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# Evaluation of the Future Brunels Programme: 2011-2015



## **Acknowledgements**

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## Executive Summary

### The Future Brunels programme

The Future Brunels programme is a STEM enrichment programme run by the ss Great Britain Trust. The Brunel Institute, the Trust's centre for conservation and education where the programme is based, celebrates the life and work of the Victorian engineer Isambard Kingdom Brunel and is home to a collection of items, the largest of which is a ship, the ss Great Britain.

The overall aim of the Future Brunels programme is to inspire young people to explore careers in science, technology, engineering, mathematics (STEM) and related areas. Each year since 2011, students in Year 7 (age 11-12) from four Bristol schools participate in a two-stage process which selects a cohort of twelve students who have enthusiasm for and a potential aptitude for science but are not necessarily committed to studying STEM subjects beyond GCSE. Each cohort of Future Brunels consists of three students from each of the four schools (Bedminster Down School, Cotham School, Merchants' Academy and Redland Green School), and participates in specially designed activities for six days each year.



Isambard Kingdom Brunel (1806-1859) is widely regarded as one of the greatest British Victorian engineers. He was responsible for several of Bristol's significant landmarks, the Clifton Suspension Bridge, the ss Great Britain and Temple Meads station. The link between the design of the Future Brunels programme and Brunel himself rests on a notion that a high achieving person such as Brunel has certain attributes and a forward-looking, inventive outlook, and as such, Brunel's perceived attributes have become the themes for the five years of the programme. In the first year, the theme is 'The Scientist' *exploring and thinking about the world*. The second theme is 'The Polymath' *connections between art and science*. This is followed by 'The Magician' *cutting edge advances in knowledge and seeing 'behind the scenes' of STEM*, and then 'The Engineer' *shaping the world and pushing the boundaries*. In the final year, the theme is 'The Human Being' *the impact of science and engineering on our lives*.

The programme is designed to contrast with young people's expectations of classroom education, working from the assumption that all manner of places exist in the city of Bristol that have potential to support the development of interest in and enthusiasm for a variety of STEM subjects, activities and careers. The programme makes impressive use of resources in the wider Bristol area, offered by the Brunel Institute's Corporate Academy members and others. Throughout the programme the Future Brunels visit both of the city's universities and a range of workplaces in Bristol and the surrounding area, meeting people whose training in science, technology, engineering and mathematics has enabled them to follow careers that range from aerospace engineering to animation,





seeing the places in which they work and being given a notion of the work that they do. To give an example, during the module 'The Polymath', which includes exploration of the skills, knowledge and technologies used in photography and animation, young people were taken on a guided tour of Aardman and spent time making their own animations using facilities at the University of the West of England.

The Future Brunels Programme was the brainchild of Matthew Tanner, CEO of the ss Great Britain Trust, and was developed by Rhian Tritton, Director of Interpretation, Collections and Education, and Rachel Roberts, Head of Education. Dr Roberts delivers the programme together with Gemma Kearsley-Wooler, Science Education Officer. Rhian Tritton leads the development and delivery team and brings to this role an ability to take risks, a creative approach and a striving for excellence that has infected the culture and practice of the Future Brunels programme.

### **Evaluating the programme**

The first cohort of Future Brunels joined the programme in 2011 and by 2016 five cohorts had joined the programme. The evaluation of the programme has focused on the first three cohorts (Cohort 1, 2 and 3) and at the time of completing the evaluation Cohort 1 had graduated from the programme, Cohort 2 was in year 11 and Cohort 3 was in Year 10. The aims of the evaluation have been to:

- track the development of the Future Brunels as they participate in the programme;
- understand the role of identity and imagined future identity on the choices young people make about future education and careers;
- identify key factors of the programme's activities and social networks that contribute to the development of the Future Brunels and their choice of future education and career;
- investigate differences between participants, with a focus on social disadvantage and educational experiences.

The approach taken to the evaluation as a whole is linked to a perspective on science learning that is supported by recent educational research. Research offers the project a well-grounded understanding of the factors that influence young people to choose to study STEM subjects, and also the factors that encourage or enable them to achieve in those subjects<sup>1</sup>.

Some of these factors relate to schools (science facilities, science teachers, and the nature of courses) while others relate to activities and experiences outside school as well as within it (careers guidance, image and interest in science and mathematics). We view it as particularly relevant to attend to the fact that the young people who are selected to become Future Brunels will, to varying extents, be growing up in social environments that may also stimulate their interest in STEM subjects. For example, diverse examples of STEM related jobs and careers may be available to them from friends, family, neighbourhood, school and the media, however there are likely to be differences between Future Brunels with respect to the breadth and depth of these experiences.

The following sources of data have informed the evaluation: research literature on uptake of STEM subjects, publicly available data on schools; census data for super output areas; detailed observations of the activities organised by the Future Brunels programme; interviews carried out with Cohort 1 and 2 and their families; focus group interviews with Cohort 3; questionnaires administered to Cohort 1, 2 and 3.

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<sup>1</sup> National Audit Office Report, 2010: Department for Education: Educating the next generation of scientists (HC 492 2010-2011).

## Tackling the decline in STEM take-up Post-16

Since the early 1990s there has been a decline in enrolment in post-compulsory subjects in science, technology, engineering and maths (STEM) and application to university level courses. The UK's national audit office published a report stating that *'A strong supply of people with science, technology, engineering and maths skills is important to promote innovation, exploit new technologies, produce world-class scientists and for the UK to compete internationally'* and research quoted made it clear that methods for encouraging young people's interest in and uptake of STEM rely on high quality science learning in the classroom complemented by learning out of the classroom. Drawing on the results of this report the evaluation of the Future Brunels programme asks the following two questions:

1. Do Future Brunels want to pursue STEM-related subjects and careers?
2. Are Future Brunels able to pursue STEM-related subjects and careers?

A review of research literature shows that it is relevant to think of young people's interest in and orientation towards science and STEM as being linked to the way that they perceive themselves and others, the routes through which they come to think about their future, and of the importance of other people in supporting and guiding them.

## Learning about the engineering practices of Isambard Kingdom Brunel

The Brunel Institute's curators introduce each new cohort of the Future Brunels to the drawings, sketches and design work of Isambard Kingdom Brunel, which are housed in the ss Great Britain Archive Vault. The evaluation study has observed that being able to study Brunel's design work is important for the Future Brunels because they learn about the processes that are involved in producing a piece of engineering, and in particular the role of sketching, reworking designs and learning from failure, engineering practices that have been identified as being important by the Royal Academy of Engineering. In having access to the processes behind successful engineering projects they are learning that the attributes of success are as much about tenacity and hard work as they are about brilliance.



## Becoming a member of the ss Great Britain community

When the Future Brunels first visit the ss Great Britain they are given badges that are identical to those worn by all employees and volunteers on the ship. They are also given sweatshirts and free passes to visit the ship with their family and friends. The evaluation study has observed that the "proper badge", being treated as equals by the ss Great Britain employees and volunteers and access to parts of the ship that are not normally accessible to the general public all contribute to the Future Brunels feeling that they are part of the ss Great Britain community. In this respect the Future Brunels begin to identify with a community of practice that is linked to the work of Isambard Kingdom Brunel.

B: .... we got our little badges and I went round with my Mum – I think it was a couple of months ago – and I wore my badge and I was walking and some little kid pointed out to me because he thought I worked there and he asked me where the toilets was. I was like 'Oh' because I knew where and I pointed and he was like



‘thank you’ and that made me feel like I am part of the team because we’ve been places that not that many people’s been before.

### **Access to the working life of scientists and engineers**

Over the course of the programme the Future Brunels visit a range of engineering firms including Dymag, Babcock, Airbus, and Renishaw. They also visit science and engineering related departments at the University of Bristol and the University of the West of England. The evaluation team has observed that these visits provide a rich source of information about the working life of scientists and engineers. For example, over the course of the visit to Renishaw, links between the science that is studied at school, the high tech products that the business develops, and the applications of those products, are made clear. At Dymag, craft and high tech processes are set into context: the craft skills of making wheels by hand is important because the company is working to perfect a process and a product, which, it is anticipated, will eventually be automated, producing greater quantities of the bicycle wheels to supply a new and developing market.

For some Future Brunels it seems that particular activity days were significant in triggering a change from no clear idea about a future career to a career in science or engineering. To give an example, one girl explained that the visit to the Crime Scene House at the University of the West of England had led her to work towards a career in forensic science.

### **Engaging with scientists and engineers**

The Future Brunels have first-hand contact with a wide range of scientists and engineers during the activity days that are spread across the five years of the programme. This includes talking to people who work in engineering industries and engineering and science departments of universities. In their discussions with these people they are introduced to specialist language as a natural part of the conversation. They find out about what these people studied at University and for their A-levels. For example, they learned that the vast majority of staff who work on computer-generated images for Aardman Animations had studied A-level mathematics.

The evaluation team has observed that in talking to scientists and engineers the Future Brunels are learning about their working lives and educational pathways. This opens up the possibility that they begin to imagine what it might be like to become a scientist or an engineer. It is important that all Future Brunels are able to have contact with people with whom they can identify and say ‘I want to be like that’ since early identification of oneself as someone who will follow a particular career path will increase the chance that appropriate steps can be taken (DeWitt et al., 2013) <sup>2</sup>.

### **The importance of “having a go yourself”**

The Future Brunels almost unanimously told us that they value activities that are complex, interactive and hands-on:

- Int: What does interactive and hands-on mean?  
B1: Actually having a go yourself.  
B2: Yeah, and getting to do a lot more stuff rather than having somebody come in to show us things. That’s interesting but I think it’s more interesting and engaging when you get to have a go at something or you get to see something that’s really complex and interesting, but you get to understand it yourself and have a go at doing things.

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<sup>2</sup> DeWitt, J., Archer, L., & Osborne, J. (2013). Nerdy, brainy and normal: Children’s and parents’ constructions of those who are highly engaged with science. *Research in Science Education*, 43(4), 1455-1476

Through the experience of “having a go” they can begin to feel and experience what it would be like to be a scientist or engineer.

### **Integrating engineering and science**

The Future Brunels Programme integrates science and engineering. We suggest that the blend of engineering and science that threads through the programme, both in terms of the design of the annual modules and the individual activity days, may be a key element of the programme that distinguishes it from other out-of-school STEM initiatives. For example both science and engineering are part of the Polymath module. Within this module Future Brunels: learn about the science behind the stereoscopic images within the Brunel collection; explore the physics of light within the pinhole camera activity day; learn about chemical processes when developing photographs; learn about technology to develop simple animations within the animations workshop and learn about the science and engineering used within the creative industry when they visit Aardman Animations.

There is evidence that Future Brunels use their experiences of science from the programme to enhance their engagement with school science. For example the visit to the sewage works helped to contextualise some science activities in chemistry as illustrated in the quote below:

- Int: Is there anything that you’ve been learning as a Future Brunel, you know through the Future Brunel days, that’s made you a bit more interested or curious about some of the things that you might be learning in school?
- B1: Um ... well some of the stuff in like the sewerage treatment place ... like some of the stuff I learnt that day like with Chemistry and stuff, makes you just realise how it’s been applied to like real like actually ... actually being applied to ..
- B2: Yeah we found out that they have these little microorganisms to eat the like sewerage.

### **STEM work experience**

Around 93% of UK school pupils undertake work experience and 50% of placements are in the summer term of year 10 (age 14–15); this is the case for all four schools attended by the Future Brunels. Relevant work experience is likely to play an important role in encouraging young people to want to pursue STEM subjects and schools often require students to organise this for themselves. Through the Future Brunels Programme many of the participants have been supported to organise work experience with one of the engineering companies that they have visited as part of the programme, for example work experience at Babcock as described below:

- B: I think it was a very good work experience compared to what I’ve heard from my friends, because we literally got to work in every aspect of the business from the engineering of making nuts and bolts to the business side, getting deals and writing a business plan of what we do, various things like that. It gave us a taste of what it would be like to work in those areas.

Organising work experience for Future Brunels whose families do not have contacts with STEM-related occupations is an important and valuable role. In general schools struggle to gain access to a full range of work placements and tend to rely on families being able to access workplaces through people they know.

### **The role of the programme leads**

Rachel Roberts and Gemma Kearsley-Wooller are the Future Brunel Programme leads. They both studied science at university (chemistry and physics respectively) and they bring their knowledge of science to their work with the Future Brunels. It is clear that the Future Brunels value their relationship with Rachel and Gemma and treat them differently from

teachers. In this respect Rachel and Gemma are female scientists with whom the Future Brunels can identify.

Int: How important are Gemma and Rachel to the programme, do you think?

G: They know how to help you. You don't feel pressured to talk to them. With teachers, it's a bit awkward talking to them, but with them it's down to earth and you can talk about anything.

### **Do Future Brunels want to pursue STEM-related careers?**

The literature reviewed shows that it is relevant to think of young people's interest in and orientation towards science and STEM as being linked to the way that they perceive themselves and others. This relates to how they think about their own identity and how they identify with others.

The overall aim of the Future Brunels programme is to encourage more young people to consider a career in science and engineering. In this respect all pathways into STEM careers, including apprenticeship routes and higher education are valued. There is evidence that the Future Brunels programme is achieving this aim. At the beginning of the programme just over half of the Future Brunels from across the first three cohorts had not chosen STEM-related careers or were unsure about a possible career path. By the end of the programme all of the first three cohorts of the Future Brunels are either thinking about STEM-related careers or are keeping their options open by choosing to study a selection of science A-levels. In this respect we consider that the Future Brunels programme is achieving its aim of inspiring young people to explore careers in science, technology, engineering and mathematics.

### **Are Future Brunels able to pursue STEM-related careers?**

The events, information, personal relationships, and other sources that feed the imagination, need to be accompanied by appropriate and well timed help and information, if a young person is to be enabled to choose and then successfully embark on a career that falls under the broad heading of science, technology, engineering or mathematics.

Research tells us that it needs to be recognised that moving from an interest or aspiration for continuing into a STEM-related career requires support to navigate the system, which for some young people is already in place (because older family members 'know the ropes') but for others, will need to be provided. This moves beyond thinking of the problem as hinging on a young person's aspiration, to a consideration of how a young person's social networks of family and friends can be used to support them in achieving their aspirations.<sup>3</sup>

Whether or not the Future Brunels are able to pursue STEM-related careers relates more to factors beyond the control of the Future Brunels programme than to the programme itself. It relates to whether or not they obtain good-enough GCSE grades to be accepted on the A-level courses they want and maybe need to study. It relates to whether or not they have readily accessible sixth forms where they can study the necessary level 3 courses for



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<sup>3</sup> ASPIRES (2013). *ASPIRES Final Report*. Available from: <https://www.kcl.ac.uk/sspp/departments/education/research/aspires/ASPIRES-final-report-December-2013.pdf>

access to apprenticeships or higher education. It relates to whether or not they obtain good-enough A-level grades to be accepted on the university courses or apprenticeship programmes they desire to follow. It relates to whether or not they have people around them who know how to navigate the higher education system.

Bristol is a divided city in terms of educational opportunities for young people. For example the Higher Education participation rate of young people in South Bristol is 16%, compared to a national average of 36%. This drops to less than 9% in the areas from which students from the two South Bristol schools are likely to live. The Future Brunels who live in South Bristol are likely to be from families where there is neither experience of Higher Education nor experience of working with STEM subjects. Therefore the young people from South Bristol have a more restricted set of resources to draw upon when thinking about their future career possibilities and related educational pathways than those from North Bristol.

The Future Brunels who live in South Bristol are less likely to obtain outstanding GCSE results in mathematics and science, and have fewer available opportunities in terms of access to level 3 Post 16 educational provision than those who live in North Bristol. For all these reasons the South Bristol Future Brunels may not have the opportunities to pursue STEM-related careers. This relates to issues of social disadvantage and the divided educational system which exists within England.<sup>4</sup> However as the Future Brunels programme has become more aware of these issues it has worked as far as possible to redress this imbalance, for example by supporting the South Bristol Future Brunels to find work experience.

## **Conclusions**

### **Inspiring young people to explore STEM-related careers**

At the beginning of the programme just over half of the Future Brunels from across the first three cohorts had not chosen STEM-related careers or were unsure about their future careers. By the end of the programme all of the first three cohorts of the Future Brunels are either thinking about STEM-related careers or are keeping their options open by choosing to study a selection of science A-levels. In this respect we consider that the Future Brunels programme is achieving its aim of inspiring young people to explore careers in science, technology, engineering and mathematics.

However, the opportunities to pursue STEM related careers are more restricted for the Future Brunels who live in the South of the City by comparison with those who live in the North of the City. This relates to factors beyond the control of the Future Brunels programme which include: GCSE grades; accessible sixth forms for studying level 3 courses; access to people who know about STEM-related careers and access to people who know how to navigate the higher education system.

### **Characteristics of the Future Brunels Programme**

The Future Brunels programme occupies a particular position within an ecology of science and engineering-related activities, and works with young people and their families as well as schools. There are a range of opportunities that open up for the Future Brunels through their involvement in the programme, and these relate to identity formation, learning experiences, conversations and networks. Overall we consider the following to be key characteristics of the Future Brunels programme:

- A development team who: are creative; are willing to take risks and pursue excellence.
- A focus on the engineering practices of Isambard Kingdom Brunel.
- An emphasis on Future Brunels becoming part of the ss Great Britain community.

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<sup>4</sup> See for example Allen, Rebecca. "Missing Talent. Research Brief. Edition 5." Sutton Trust (2015).

- An emphasis on integrating the practices of both engineering and science throughout the programme.
- Giving Future Brunels access to the working life of engineers and scientists.
- Enabling Future Brunels to engage with scientists and engineers.
- Allowing Future Brunels to have-a-go themselves.
- Supporting STEM work experience.





## Introduction and Aims of the Evaluation

Future Brunels is a STEM (science, technology, engineering and mathematics) enrichment programme based at ss Great Britain Trust, a museum and visitor attraction which celebrates the life and work of the Victorian engineer Isambard Kingdom Brunel. The Trust cares for a collection of items, the largest of which is a ship, the ss *Great Britain*. Designed by Brunel, it was launched in 1843, and brought back to Bristol in 1970. This ship, and the objects in the collection, are used as resources for a variety of learning programmes run by the Brunel Institute, on subjects such as Brunel himself, maritime history, archaeology, science and engineering. Significant amongst these is the 'Future Brunels' programme, which aims to encourage young people to consider a career in science and engineering. The programme originated in the realisation that ss Great Britain Trust's education team had the potential to run a long-term project that could enthuse a series of cohorts of young people in STEM subjects. The programme has run for just over five years.

In late spring each year, 12 young people join the programme as the new cohort of Future Brunels. They are selected from four Bristol secondary schools and selection is based on aptitude, attitude, and potential rather than existing attainment. Each year they spend six days, spread across the academic year, participating in activities at the museum and at other locations in the city, around it and occasionally further afield. The locations are chosen and activities designed by the programme team on the basis that they bring science and engineering alive, and are organised according to a series of themes selected on the basis of Brunel's talents - as an engineer, entrepreneur, artist and designer<sup>5</sup>.

In its work to ensure effectiveness, the Brunel Institute engaged the Graduate School of Education at the University of Bristol as evaluators. The aims of the evaluation have been to:

1. track the development of the Future Brunels as they participate in the programme;
2. understand the role of identity and imagined future identity on the choices young people make about future education and careers;
3. identify key factors of the programme's activities and social networks that contribute to the development of the Future Brunels and their choice of future education and career;
4. investigate differences between participants, with a focus on social disadvantage and educational experiences.

The evaluation has been based on a number of assumptions. Young people's attitudes, knowledge and skills develop as they participate in a variety of communities and practices both within and out of school. The young person's *identity* within such communities and practices is relevant both to what and how he or she learns. Participation in different communities informs the *range of potential identities* that a young person imagines for him or herself. From this perspective, the Future Brunels programme offers young people the opportunity to participate in a new STEM-related community of practice, one which lies outside (but is related to) their school. We would expect young people's *attitudes* towards STEM subjects to be informed by the nature of the activities in which they participate and also by the attitudes and interests of the people with whom they spend time, including friends, family, teachers and other adults. Future Brunels will make sense of their participation in the programme's activities by reference to previous related experiences and activities. Moreover the emerging community of Future Brunels will develop as the young people participate within this community and will be influenced by other communities in which they are involved.

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<sup>5</sup> Evaluation of the Future Brunels Programme Report for Year 2. The first cohort: 2011-2013.

The implications for the evaluation project have been that:

- the Future Brunels have been viewed as an emerging community of practice that relates to the practice of scientists and engineers;
- attention has been given to out-of-school communities (families, friendship circles) as well as school communities;
- there has been a particular focus on the transformation of engagement of the Future Brunels in out-of-school activities and communities, as well as those at school;
- attention has been paid to identities, including imagined future identities.

The approach taken to the evaluation as a whole is allied with a perspective on science learning that is supported by recent educational research. Research offers the project a well-grounded understanding of the factors that influence young people aged between 14 and 18 to choose to study STEM subjects, and also the factors that encourage or enable them to achieve in those subjects (National Audit Office Report, 2010).

Some of these factors relate to schools (science facilities, science teachers, and the nature of courses) while others relate to activities and experiences outside school as well as within it (careers guidance, image and interest in science and mathematics). We view it as particularly relevant to attend to the fact that the young people who are selected to become Future Brunels will, to varying extents, be growing up in social environments that may also stimulate their interest in STEM subjects and/or their interest in future employment for which qualifications in STEM subjects are needed.

The evaluation has had both a formative and a summative element. In terms of formative evaluation regular meetings have been held with the project team to provide a forum for discussion and informal feedback on the basis of information that the evaluation team has collected about the programme, which includes observation of activity days. In terms of summative evaluation, reports have been produced for both internal and external purposes. Two full reports, produced in September 2012 and October 2013, set out a range of recommendations (see Appendix 3).

In section 2 of this report we review the relevant literature that provides a framework for the empirical aspect of the evaluation. Within section 3, we describe the diverse aspects of the Future Brunels programme and the particular ways in which the City of Bristol is used as a resource. Section 4 begins to address the third aim of the evaluation, namely to identify the key factors of the programme's activities and social networks that contribute to the development of the Future Brunels and their choice of future education and career. Within section 5 we address the first aim of the evaluation which was to track the development of the Future Brunels as they participate in the programme. Section 6 focuses on the fourth aim of the evaluation, to investigate the differences between participants with a particular focus on social disadvantage and educational experiences. Within section 7 we draw on the



differences between Future Brunels with respect to identity, awareness and opportunity in order to argue that, in general, Future Brunels from South Bristol need additional support and resources if they are going to realise their aspirations to become scientists and engineers. Throughout the report we engage with the second aim of the evaluation, namely to understand the role of identity and imagined future identity on the choices young people make about their future education and careers.

## Review of Relevant Research

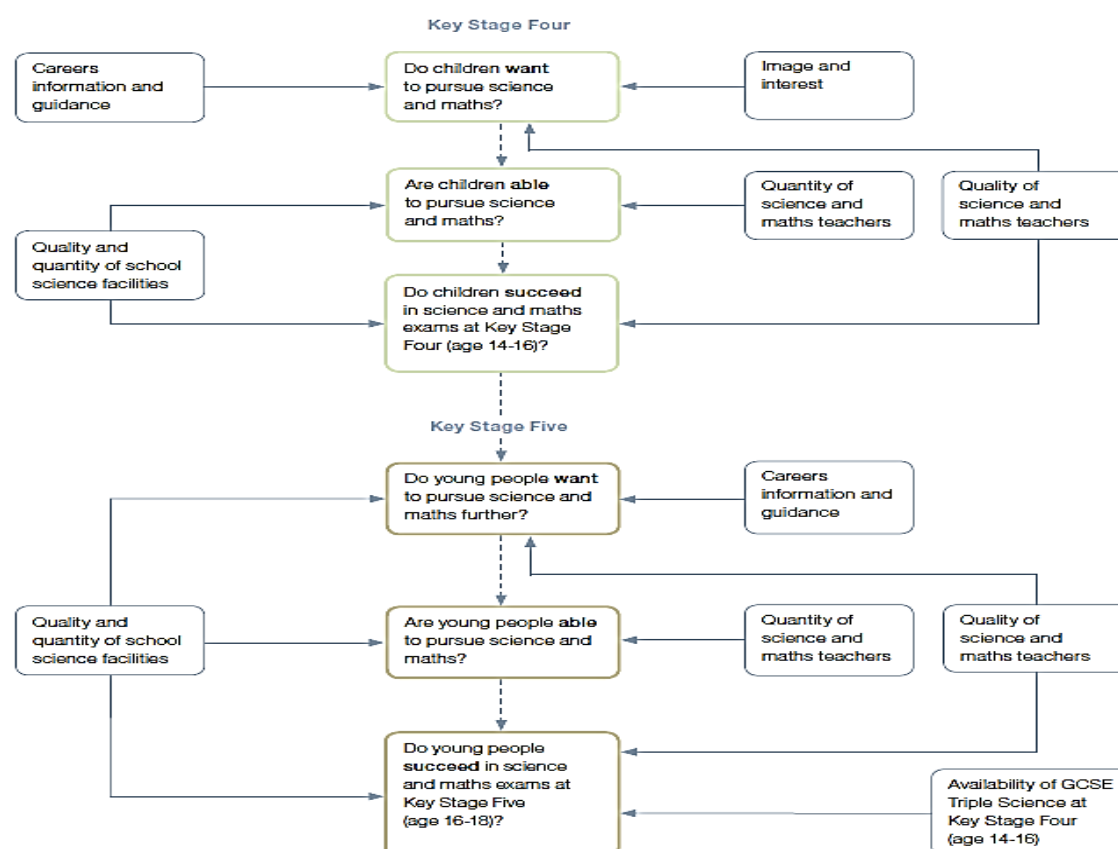
### Young people's interest in science, technology, engineering and mathematics (STEM)

Since the early 1990s there has been a decline in enrolment for STEM subjects in post-compulsory education and in applications to university level courses in STEM subjects. Detailed information about young people's interest in and attitude to STEM subjects has been provided by international comparative studies (Trends in International Mathematics and Science Study (TIMSS); Programme for International Student Assessment (PISA)). The studies show that the trend away from science subjects is strongest for young people in developed countries (Bøe et al., 2011).

In response to the decline in young people's uptake of science courses, steps have been taken to further understand this decline in interest; and initiatives have been set up to encourage young people towards taking up science related careers and to encourage them to develop a lifelong disposition towards science. In the UK, the National Audit Office has stated that *'A strong supply of people with science, technology, engineering and maths skills is important to promote innovation, exploit new technologies, produce world-class scientists and for the UK to compete internationally'* (National Audit Office Report, 2010, *ibid*). The following diagram, taken from the National Audit Office report, offers a set of factors for success in improving take-up and achievement in science and mathematics, and sets out the relationships between them.

**Figure 2.1 Critical success factors in improving take-up and achievement by young people in science and maths.** Taken from: National Audit Office report: *Educating the next generation of scientists* (2010) p.11

Critical success factors in improving take-up and achievement by young people in science and maths



Source: National Audit Office literature review and survey of 1,274 children and young people

The diagram indicates that some factors that influence take-up and achievement are associated with schools (facilities, teachers, and the nature of courses provided); other factors (careers guidance, image and interest) relate to activities at school but also to those outside school – within family life, and in society at large. There is, therefore, considerable scope for projects run outside schools to influence young people's take-up and achievement in science and mathematics (Bennett & Hogarth 2009).

### How is the term STEM understood?

STEM has become a familiar term amongst policymakers and those involved in education and it is sometimes used interchangeably with the term 'science' which does not entirely capture the complexity of the definitions, nor does it suggest the variety of skills that will be necessary to participate in professions and trades in the future. Here, we expand on particular aspects of the meaning of the term, first referring to some useful definitions provided by the US National Assessment Governing Board (National Assessment Governing Board 2010).

- An **application of science** is any use of scientific knowledge for a specific purpose, whether to do more science; to design a product, process, or medical treatment; to develop a new technology; or to predict the impacts of human actions;
- **Technology** is any modification of the natural world made to fulfil human needs or desires;
- **Engineering** is a systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants.

A report from the UK Royal Academy of Engineering entitled 'Creating Systems that Work - Principles of Engineering Systems for the 21st Century' is explicit in saying that contemporary engineers need *creativity, analysis, judgment and leadership* and sets out a set of six principles: *Debate, define, revise and pursue the purpose. Think holistic. Be creative. Follow a disciplined procedure. Take account of the people. Manage the project and the relationships* (Royal Academy of Engineering, 2007).

We begin the next few sections by touching on a vision of the skills and knowledge that future generations will need, then move to outlining some approaches taken to understanding young people's feelings, ideas and engagement in science and/or STEM subjects. Disciplines that contribute to the field include cognitive psychology, sociology and psychoanalytic theory; there is no unique way of understanding attitudes to science and STEM. The remainder of this short literature review attempts to illustrate how attitudes to science and STEM have been investigated and to introduce some of its complexities, as well as setting out what has been discovered.

### Scientifically literate populations and a vision of the future world

As was discussed above, international comparisons such as PISA are not designed to assess the skills that might produce future scientists, technologists, engineers and mathematicians – rather, they place emphasis on 'scientific literacy' as being important for young people. Their description alludes to a present and future world that is more strongly concerned with and shaped by science and technology:

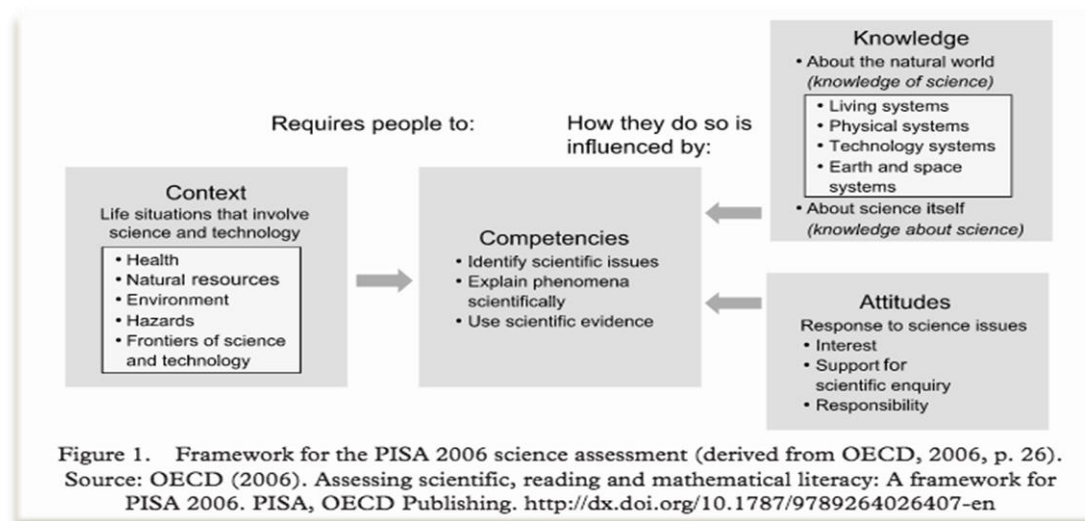
...the scientifically literate person would have an interest in scientific topics; engage with science-related issues; have a concern for issues of technology, resources, and the environment; and reflect on the importance of science from a personal and social perspective. This requirement does not mean that such individuals are necessarily disposed towards science itself. Rather, such individuals recognise that science, technology and research in this domain are an essential element of contemporary culture that frames much of our thinking. (OECD, 2013).

PISA makes a distinction between ‘attitudes towards science’ and ‘scientific attitudes’, on the basis of reviews of academic literature (Gardener, 1975; Osborne et al., 2003)

- **‘scientific attitudes’**, a complex mixture of the longing to know and understand, a questioning approach to all statements, a search for data and their meaning, a demand for verification, a respect for logic, a consideration of premises and a consideration of consequences.
- **‘attitudes towards science’**, which are the feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves.

### Attitudes towards science

The research that underlies the PISA study draws on cognitive psychology and the studies refer to a body of work that seeks to define and model interest, the development of interest in young people, and to investigate the interaction with or interest in knowledge. The separation between attitude/interest and knowledge is shown in the following diagram, which is taken from the framework for the PISA science assessment, 2006.



### Figure 2.2 Illustration of the perspective behind the PISA approach to assessing attitude to sciences

The tendency to separate affect or feeling from content and cognition is interesting in the light of more recent work in neuroscience which has questioned the validity of a dichotomy between cognition and feeling (Immordino-Yang & Damasio, 2007). Nonetheless the separation is still influential as the basis for international comparison and a body of psychological studies (Krapp & Prenzel, 2011; Krapp, 2002; Renninger et al., 2014; Potvin & Hasni, 2014)

Investigations that rely on these models have not reliably identified pathways or processes (Osborne et al., 2003). Nor have they produced evidence of clear patterns of experiences that triggered interest, as one study reported:

Overall, our findings indicate that individuals who complete STEM degrees have quite varied histories and that the triggering of their interest happened across a wide age spectrum. Similarly, in terms of who was involved or what their triggering experience was, the general results support the notion that there are many pathways to STEM with no clear preferential pathway (Maltese et al., 2014 p. 959).



## Knowledge and interest

A set of recent studies in the UK named *Understanding Participation rates in post-16 Mathematics and Physics* (UPMAP) query whether it is necessarily appropriate to separate interest or motivation from subject knowledge, as the PISA studies do. The authors write:

A common conceptualisation of students who are self-regulated learners is that they are motivationally and behaviourally active in their own learning. However, such theories of learning do not differentiate between different types of motivation that create subject interest such as dispositional differences (e.g. for intrinsic reasons such as enjoyment) or extrinsic reasons (such as career prospects, being motivated in a subject simply because students are good at it or to appease significant others), and there are also subject matter differences (e.g. reasons for wanting to do well or continue within a subject may be different for physics compared with another science, and reasons may be even further removed for subjects such as art) (Mujtaba & Reiss, 2014 p. 373).

The results of the UPMAP studies paint a complex picture of *interest* in studying physics, including showing an importance of both extrinsic factors (the “*belief that obtaining a post-16 qualification in physics would be useful for some quantifiable reward, e.g. for access into higher education or future employment prospect*” (Mujtaba & Reiss 2014, p.372) and intrinsic factors. Intrinsic factors were not so much the enjoyment of classroom activities such as discussing ideas and doing experiments; they related more strongly to the students’ own intention to continue studying the subject, and the factor that was of particular significance in supporting this intention to study was the encouragement of teachers.

These results point towards the importance of social others and to an imagined future, and it is to work that centres on these concepts that this review now turns.

## Identity and aspiration

The period during which school subject choices are made is one in which young people are thinking about their identity – their own self in relation to what they experience around them and what they encounter, including media of all kinds. Academic research that puts identity in centre place in relation to young people’s subject choices and ideas about their future includes the Relevance of Science Education (ROSE) project (Sjøberg & Schreiner, 2007), which collected questionnaire data from students in 40 countries, evaluating young people’s responses with reference to the way people understand themselves and their surroundings in the cultural, political and economic characteristics of the present-day post-industrial period. In the same vein, a UK based study that analysed transcripts of interviews held with students aged 10-14, and with their parents (DeWitt et al., 2013), was concerned with the examples of people who were perceived as scientists and “*could serve as reference points for notions of like me*”. The analysis carried out by the ROSE study suggested rather a different story from the received wisdom that there is a general decline in interest in science and technology subjects. Instead, it showed that the problem was one of a decline in *willingness* to choose to study science and technology and to orient oneself to a related career, and that this related to perceived values and images. The interviews carried out for the UK based study were able to examine popular constructions of scientists and science amongst young people, discovering that portrayals and conceptions of scientists as clever or specialist, rather than being images to which young people might aspire, might be taken to suggest or even to demonstrate that science was ‘different’ and ‘not for me’. Research that takes a similar approach has confirmed that choosing to study science and to be a scientist continues to represent a problematic path for many young people at a point when ‘identity work’ is focused on their day-to-day concerns (Carlone et al., 2014).

While on the one hand these studies point to portrayals and conceptions of scientists as sometimes less than helpful “*reference points for notions of like me*”, this does not, of course, imply that personal contact with certain individuals *is* not important in young people’s

motivation and decision making. However there is substantial evidence that parents and teachers fulfil this role more effectively than celebrities (Sjaastad, 2012).

As part of its research programme into students' interest in and uptake of mathematics and physics subjects, the UPMAP team interviewed those who had actually made the commitment to study the subject physics at university. Amongst the undergraduate physicists they interviewed, they found that an identification with a key person representing physics was important:

With respect to the question '*why did this young person choose to study physics?*', all of the seven physics undergraduates' interviews indicated the hitherto unexpected centrality of the importance of a significant adult representing physics. This interpretation came not only because of what the interviewees said – although each referred to physics being personified in some sense – but also because of what they did not say: none of the physics undergraduates suggested that an intervention, such as a project, was key to their participation (Rodd et al., 2013, p. 160)

Another UK study, the ASPIRES project (ASPIRES, 2013) described how a key factor affecting the likelihood of a student aspiring to a science-related career by the age of 14 is the presence, within the family, of science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g., knowing someone who works in a science-related job). The ASPIRES team, based at King's College London, uses the term *science capital* to refer to the presence, within the family, of science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g., knowing someone who works in a science-related job). One of the key findings of their study is that young people who come from families with medium or high science capital are more likely to aspire to science and STEM-related careers and are more likely to plan to study science post-16.

Meanwhile the UPMAP study, echoing the observation that in a world where young people are expected to choose their own futures there has been a decline in willingness to choose STEM, turned to consider families rich in science capital, and went on to ask a question about how an understanding of the nature of 'work' in STEM can be made visible within the family:

How can young people be turned into physicists, mathematicians or engineers when there is no identification? Given the discourse of life-designing in economic-driven societies, can we reckon on children following in their parents' footsteps? Even the nature of the work of scientifically technical people is such that it is done away from a child's eyes. So science is double damned: more scientists are 'needed', yet the children of scientists are not generally drawn into practices through 'legitimate peripheral participation' (Rodd et al., 2013, p.164).

Our general conclusion is that identity is important, and that some children will be growing up in families that give them access to informal experiences that relate to STEM and to people with whom they can identify. However for many young people, access to informal experiences of STEM, to people with whom they might identify, and to the varied worlds of STEM-related employment, will be relatively unusual within the course of their everyday life. The gap that is evident between these two groups of young people widens when considering how they get access to information about jobs and careers. Regardless of the availability of careers information, a study of young people aged 11-14 (Key Stage 3) found that family and friends are the most likely source of information, and subject teachers and careers advisers are generally less important to the young people who consult them (Hutchinson et al. 2009). Young people also rely on information from family and friends when they are in Key Stage 4, aged 14-16 and thinking about what to do after age 16; and, as we have discussed, the advice that family and friends provide is likely to be based on the experience and knowledge that they have gained in their own lives (Gorard & See, 2008). The impact of what is available through family and friends, is, therefore, of considerable importance.

## Choosing STEM and navigating the system

The literature reviewed here has shown that it is relevant to think of young people's interest in and orientation towards science and STEM more generally as being linked to the way that they perceive themselves and others, the routes through which they come to think about their future, and of the importance of other people in supporting and guiding them. It has shown that contemporary constructions of science and scientists in popular culture plays a part in the way that young people think about themselves in relation to STEM and scientists, and that even a 'positive image' of science and scientists which could be construed as aspirational, can in fact be counterproductive.

We do know that although varied societal pressures act to dissuade young people from STEM subjects and careers, there are numerous examples in which people do choose to follow a STEM path in the face of conflicting pressures. Professor Valerie Walkerdine has studied what makes it possible for young people to overcome pressures and perceived barriers and to follow their chosen areas of study and careers and draw attention to the link between the interest in becoming a certain kind of person – which she discusses as involving fantasy and imagination – and the steps that would need to be taken to become that person. Discussing young people's aspirations and the lower rates of working class-students access to higher education, she says: *I suggest that such students may not lack a way of fantasising a set of desires for the future, but are not well supported in education to mobilise these into an imagination which can be acted upon* (Walkerdine, 2011, p. 256).

Walkerdine illustrates this point further:

It is not uncommon for professionals with a working class background to talk of a television programme or other media product which shaped their fantasies of the possibility of something else. This would hardly be surprising in a world in which such possibilities for another kind of life are endlessly paraded across our screens. However, as I have already suggested, it is one thing to have a fantasy of being different or differently located in a life more interesting, exciting, glamorous for example, and quite another to make the transition to another kind of life through higher education (Walkerdine, *ibid*, p. 259).

Walkerdine's point reminds us that the factors that relate to a young person coming to make a decision to take up STEM subjects, relate to more complex matters than can be summarised by *attitudes to science, interest, or identity*. The events, information, personal relationships, and other sources that feed the imagination, need to be accompanied by appropriate and well timed help and information, if a young person is to be enabled to choose and then successfully embark on a career that falls under the broad headings of science, technology, engineering or mathematics. A recent review of literature, entitled "*Who you know, what you know and knowing the ropes: a review of evidence about access to higher education institutions in England*" (Whitty et al., 2015), discusses whether it is still appropriate to think of the problem as being one that hinges on the young person's aspiration, in the light of research that shows how important it is for young people to have others around them who know how to 'navigate the system':

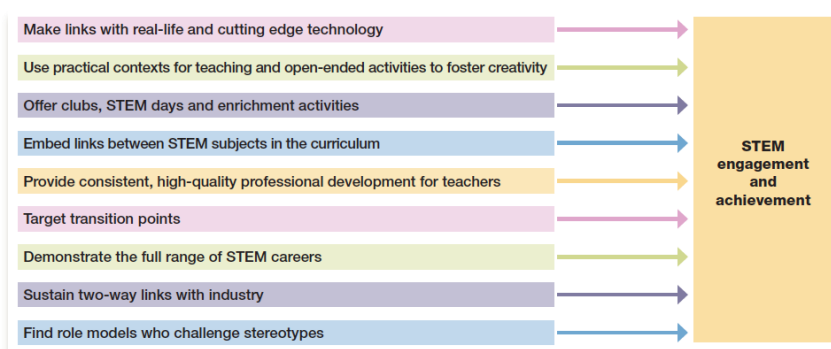
Bok (2010), drawing on work in Australia, argues that students from lower socio-economic backgrounds do have aspirations about going on to higher education, but 'have less developed capacities to realise them'. They therefore have 'to perform in a play without a script' ((Bok, 2010, p. 163). Despite their aspirations, they do not 'know the ropes' to use our own expression. Put another way, experiences and cultural capital affect 'navigational capacities' (Appadurai, 2004), which vary between those from different backgrounds.) The ability to navigate educational pathways is also seen by Bok to be 'influenced by students' access to "hot" knowledge' provided by families and local networks (p. 176), which has huge implications for those who are 'first in family', especially in terms of entry to 'elite' institutions. (Whitty et al., 2015, p. 44)

This work tells us that what is required is a recognition that moving from an interest or aspiration for continuing into a STEM related career requires some help with navigating the system, which for some young people is already in place (because older family members ‘know the ropes’) but for others, will need to be provided.

### **No one ‘fix’: diverse approaches**

In this review thus far we have added some complexity to the ideas of ‘careers guidance, image and interest’ discussed in the audit commission report. We have drawn attention to the social nature of young people’s decision-making, the relevance and complexity of identity in young people’s interest in science and ideas of their future selves, and the importance of having access to people who ‘know the ropes’ in the sense of understanding, and being able to advise the young person which of the choices they make at various points during a school career will close down or open up further possibilities.

The message emerging is that methods for encouraging young people’s interest in and uptake of STEM rely on high quality science learning in the classroom complemented by learning out of the classroom; and that there is no one ‘fix’ in terms of what should be provided outside the classroom. A review of ‘what works’ written by the National Foundation for Education Research (NFER), suggests that a diversity of approaches, inside and outside the classroom, can together lead to positive change (Straw & MacLeod, 2013). The key points from this report are shown in figure 2.



**Figure 2.3 Key points in NFER report *Improving Young People’s Engagement with Science, Technology, Engineering and Mathematics* (Straw & MacLeod, 2013)**

The NFER report also flags up the importance of careers guidance from an early stage:

In addition, our research evidence strongly suggests that careers education and guidance should be provided earlier than Years 9–11 to encourage the uptake of STEM subjects. Schools must have access to the appropriate resources to provide this effectively (p. 3).

## Developing a 'third space'



Reiss draws on a range of authors (Stocklmayer et al., 2010; Moje et al., 2004) in offering the idea of 'third space' to think about non-school spaces.

Building bridges is a necessary part of what makes third space because it helps learners see connections, as well as contradictions, between the ways they know the world and the ways others know the world...Unlike the bridge perspective, however, a third space focused on cultural, social and epistemological change....is one in which everyday resources are integrated with disciplinary learning (Moje et al., 2004, p. 44).

The term 'third space' is not just physical but social. Underlying the idea is the assumption that within these spaces are *'groups that are socially convenient to the learners and supportive of their interactions, in ways that promote multigenerational learning'* which can give the student the potential to develop conversations about *'the relative value of scientific, abstracted knowledges vis-à-vis personal, experienced knowledge'* (ibid, p.28). It offers a way of thinking about the value of science learning environments (such as museums) as offering both a social and a physical context in which connections between conceptual knowledge and everyday experience can more readily be made than in more formal environments (such as schools) or less formal ones (such as the home).

A recent report, this time focussing on out-of-school provision that supports engagement in STEM, has examined the nature and interconnections between the various approaches in the UK, reviewing what is available and what might be missing. This study was commissioned by the UK's Wellcome Trust, a body that has funded initiatives to support science learning across museums, science centres, broadcasting, performance and gaming, in the belief that doing so would help to produce a public that is both inspired by and engaged with science, its development and its application. In the words of the authors of the study,



...communities, and the complex learning infrastructure of intersecting educational entities they contain, are not mere “backdrops” for science learning; they are dynamic learning environments in which people engage, interact, and make sense of the science they encounter in their daily lives. There is increasing evidence that individuals develop their understanding of science concepts in and out of school using a variety of community resources and networks through an accumulation of experiences from different sources at different times (Falk et al., 2015).

We have touched on the valuable role that museums and science centres may occupy within a whole ecology, when the world that young people are growing up in is considered as a complex system of multiple parts that come to bear on young people’s engagement and learning of science. Shifting the lens to consider the detail of what takes place within museums and science centres, we draw on literature that asks how, for the young people who move in and out of these spaces, links are made between what they see and do and what happens within the school system and the everyday world.

### **New directions: diverse and interconnected resources**

Accepting the challenge of the interconnectedness and potential value of a very diverse range of activities and resources, the UK-US researcher-practitioner partnership named ‘Youth Access & Equity in Informal Science Learning’ draws on the ecologies metaphor and chooses to put their focus on the trajectory young people take in their learning and development of identity. This body of work seeks to *understand how youth move within/across/through learning spaces toward possible futures. How youth choose to engage science, for what purposes, where and when all shape, and are shaped by, the people, places, events, and power structures that constrain or expand activity.* They quote the value of a very diverse and sustained approach and contrast it with one-off science engagement activities: *“No one-off event is going to cut it in terms of making real impact on social inequalities and wide science engagement. The appeal of the pathways model is that it means no one person or organisation has to try to do it all”* (Archer et al., 2015, p.2).

Rather than a focus on the design and implementation of science engagement activities, the focus of this body of work is on the young people themselves as actors within a complex world: *the agency youth have to author their lives within/across the multiple layers and contexts of learning experiences in science.* This new approach has a perspective that is relevant to thinking about the Future Brunels, their varied lives, and the programme designed to stimulate and support their developing interests.

### **Concluding remarks**

On the basis that the Future Brunels programme occupies a particular position within an ecology of science-related activity and it works with young people through and with their families as well as schools, we suggest that interesting possibilities may open up for young people through their involvement in the programme, in ways that link with identities, experiences, conversations and with learning opportunities that have taken place with other people in different social contexts and in other environments. In the sections of the report that follow, we outline the programme and then examine the responses and reflections of the Future Brunels in their own words, attempting to tease out the links and associations that they are making, and through them to begin to discuss how much, and how far, the programme has been able to ‘make a difference’.

## The Future Brunels Programme

A programme based on the inventions and attributes of Isambard Kingdom Brunel



Isambard Kingdom Brunel (1806-1859) is widely regarded as one of the greatest Victorian British engineers. He was responsible for several of Bristol's significant landmarks, the ss Great Britain itself, Temple Meads Railway Station, and the Clifton Suspension Bridge. The history of Brunel's involvement with this bridge can be told as a story about a young man, trained in the scientific method, who pits his wits against traditionalists and their adherence to their own way of doing things:

Telford came to the conclusion that the 600ft. span of the Menai Suspension Bridge was the safe maximum and that no suspension bridge of greater span could offer sufficient resistance to lateral wind pressure. For this reason he rejected all the four designs which Brunel had prepared for the competition because they had spans varying from 870 to 916ft. Telford's attitude towards his bridge was (...that...) having arrived at a successful design by a process of trial and error he refused to believe that anyone could improve upon it, least of all a young man who had only built bridges on paper. In fact Brunel had visited the Menai, studied the bridge closely and found an answer to the snags which had troubled Telford. He designed a better type of suspension chain and he arranged the suspended arc of the chains in such a way that at the centre of the bridge platform the suspension rods were extremely short. This made his designs much more resistant to lateral pressure (Rolt 1958).

Brunel's father, Marc Brunel, was, like Telford, *a member of a pioneering generation of engineers whose approach to problems was empirical and who acquired much of their knowledge by experience*, and oversaw his son's education, including showing him his own work and setting him tasks relating to engineering, then eventually sending him to study

mathematics in France, followed by an apprenticeship in the making of clocks and scientific instruments with a master horologist.

The link between the design of the Future Brunels programme and Brunel himself rests on a notion that a high achieving person such as Brunel has certain attributes and a forward-looking, inventive outlook, and as such, some of Brunel's perceived attributes have become the themes for the five years of the programme. In the first year, the theme is 'The Scientist' *exploring and thinking about the world*. The second theme is 'The Polymath' *connections between art and science*. This is followed by 'The Magician' *cutting edge advances in knowledge and seeing 'behind the scenes' of STEM*, and then 'The Engineer' *shaping the world and pushing the boundaries*. In the final year, the theme is 'The Human Being' *the impact of science and engineering on our lives*. For each year of the programme, six activities are organised for each cohort, taking place during school term time, and the Future Brunels have special permission to leave school for the day and attend these enrichment activities rather than the school programme<sup>6</sup>.

### Diverse approaches; using the city of Bristol as a resource



In designing a series of activities to fit the annual themes, the Education Team at the ss Great Britain draw on the resources in the city, including the workplaces and sites represented by the Brunel Institute Corporate Academy members and others. The team capitalises on the wide range of places that exist in the Bristol area that have potential to support the development of the Future Brunels' interests in a variety of STEM subjects, activities and careers. This includes visits to unusual places including a sewerage works and a well-known animation studio, as well as those more commonly associated with Brunel (the docks, the Clifton Suspension Bridge) and with engineering companies associated with transport, aviation and defence.

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<sup>6</sup> See Appendix 3 for an example programme of activities.



By the end of the five year programme the first cohort of Future Brunels had visited both of the city's universities and an impressive variety of workplaces in Bristol and the surrounding area, and met people whose training in science, technology, engineering and mathematics (STEM) has enabled them to follow careers that range from aerospace engineering to animation. Importantly they have seen at first hand the places in which people who have chosen to study STEM subjects have found work, and have been able to develop a sense of what this day-to-day work is like. The evaluation team has observed many of the activities; the following gives just a brief, though detailed, illustration of a small number, chosen principally because they were the activities to which the Future Brunels referred when we interviewed them in focus group meetings in the summer of 2015.

### **STEM and the city's creative industries: Animation and photography**

During the module 'The Polymath', which includes exploration of the skills, knowledge and technologies used in the production and manipulation of images, the Future Brunels are told about some of the science and mathematics behind photography while at the same time they make a pinhole camera which they go on to use to produce a solargraph - a long-exposure image that shows how the path of the sun across the sky changes with the planet's tilt. These cameras are taken home to put in position outdoors pointing south towards the sun. When six months have elapsed, the camera is opened, and the paper shows a series of trails.

Later in the year, as part of the Animation elements of the Polymath theme, Cohort 1 of the Future Brunels were taken on a guided tour of Aardman, and then, in a follow-up session some weeks later, they spend time at the University of the West of England, making their own animations. As they tour the two Bristol sites in which Aardman is based, they see a very broad cross section of the working environment, visiting departments that range from IT support for the enormous computational demands of the industry, to the rooms housing the display boards used for project management. They visit the lighting department and studios, and the rooms in which BAFTA and OSCAR awards are displayed. Over the course of the tour, the links between STEM subjects and the creative work of the industry are made explicit. To give an example, two animators in the CGI (Computer Generated Images) department explained that they wanted to show the Future Brunels something of the relationship between mathematics and animation. They began by showing something familiar to school students – a sheet of graph paper, with the familiar x and y axes, used for graphical representation in mathematics, sciences and engineering. The animators explained how they worked with a third axis, z, to make the third dimension, and when programming, used coding that specified x, y and z, co-ordinates in three dimensional space and also coding for red, blue and green, producing 3D colours. Having given this outline explanation of the coding they use, they returned to graph paper, this time showing a sine wave, then described how they built up from mathematical structures to make an animation of the waves in the sea, then showed how it was used in the film 'The Pirates! In an Adventure with Scientists!'. The animators emphasised that in the course of developing an animation of the sea everything produced was computer generated, and that what was important for their work was an understanding and facility with mathematics.

### **Resources in and around the city: Engineering firms**

Over the course of the 'Engineer' theme, the Future Brunels visit a variety of local firms including Dymag, Babcock, Airbus, and Renishaw. Dymag is a small business making innovative carbon fibre wheels, at which the Future Brunels are shown the processes of design, making and marketing. They are invited to handle materials to discover for themselves how much they weigh. As well as meeting people whose work involves making wheels by hand, they meet engineers who work at computers, using CAD for design, and then, in the next room, find out how instructions from the designers are transferred by the machine into actions that are carried out by a CNC mill, which cuts the material into the designed shapes.

During their visit to Dymag, the processes are set into context: the craft skills of making wheels by hand is important because the company is working to perfect a process and a product, which, it is anticipated, will eventually be automated, producing greater quantities of the wheels to supply a new and developing market. Similarly, work that is begin carried out to help market the product is made evident: during the visit, a cyclist who cycles with carbon fibre wheels, a member of a diabetic cycle racing team that Dymag sponsors, arrived on his bike, dressed in his racing lycra with the team colours and sponsors' logo.

At Renishaw, an established business on its own site in a rural area near Bristol and a very different scale from Dymag, there are facilities for showing visitors the applications of technologies for precise measurement to jet engine and wind turbine manufacture, dentistry and brain surgery. The Future Brunels day at Renishaw began by setting the organisation in its historical and scientific context, with videos and talks which ranged from the story of how two men set the company up, to explanations of how small a nanometer is and what are the benefits of measuring on such a small scale. The links between the science that is studied at school, the high tech products that the business develops, and the applications of those products, are made clear. To give an example, after an illustrated explanation of spectroscopy, the Future Brunels were shown the Raman microscope, a laser-based device that Renishaw started developing some twenty years ago. They were shown that it can be used to see the distribution of components, and an example of an applications given: it has been detecting the chemicals in a powder in order to find out if it contains illegal drugs, and in detection of the pigment used in the Vinland map. The map had seemed to indicate that the Vikings had been to America before Columbus; however, using a Raman microscope showed that two forms of the pigment titanium oxide had been used, of which one was a form that has only recently been in existence, and therefore the map was not authentic. The Future Brunels were shown that amongst the advantages of measuring with laser-based devices is that they don't need to touch the material they are measuring, which is clear for heritage artefacts such as ancient maps, and in health applications, where lasers are also used for treatment, measuring (and therefore detection) using lasers can be followed immediately by laser surgery. The Future Brunels were impressed by the fact that there is then no need to physically cut non-diseased parts of the body, which would have been necessary in the past.

As with their visit to Dymag, the context for Renishaw's products was discussed, with the advantages to businesses made clear: *What sells the product is a reduction in time to do the measurement. You can't sell measuring but you can sell reducing the time, because it makes a massive saving.*

Access to engineering and scientific processes during the visit to Renishaw was illuminating for many of the Future Brunels.

Boy: I suppose it was getting involved in the industry, seeing how it's done, and learning about lots of different principles and how the same technology can be applied in different ways.



The Future Brunels also visit engineering businesses in and around the city. Cohort 1 visited Airbus, and the defence engineering branch of Babcock, and in each case met young graduate and apprentice engineers, who showed them the sites, answered questions and devised participatory activities. The Babcock engineers divided the Future Brunels into teams to compare the trajectories of cardboard rockets powered by air pressure, using everyday equipment (a foot pump and a tape measure), relating the task to a real-life



decoy launching problem that the engineers had worked on themselves. Following the activity they were shown the engineering solution to the problem and then taken to the engineering workshop where they saw individual parts of the launcher made out of finely-engineered steel. At Airbus, they were asked to make sets of choices for aircraft, selecting a fuselage, an engine, a wing, and a tail, from a pile of illustrated cards, deciding where they would mount the engine. Teams scored points for the range and fuel consumption calculated on the basis of their chosen designs. A series of rounds of the game took place, after which the engineers revealed which set of choices was closest to the performance of the aeroplane that makes Airbus the most money. The first cohort of Future Brunels became very interested during this task and began asking questions, asking, for example, about reasons for mounting the wings in different places, which led to discussions of issues arising from airflow, or the need to balance weight according to the purpose of the plane.

### The science in a magician's world

Throughout the Magician theme, the Future Brunels are introduced to magic and the scientific secrets behind illusions. Early in this theme, a magician and science instructor explained that magic revolves round understanding people's expectations, and surprising them: *you pull the rug out from people's expectations*<sup>7</sup>. During the magic session based at Brunel's ss Great Britain, the Future Brunels were taught a series of tricks, interspersing them with a discussion about how the brain works. To give an example, they were shown that *if you force people to make a quick decision, you'll get certain answers. Think of a flower – rose, think of a random number – 7. Odd numbers feel more random than even, and you are not likely to choose the one in the middle, so you'll say 1 or 7. If you ask what colour is your fridge, and then ask what do cows drink, you form links in people's minds (white, milk, cow, milk) which directs them towards a particular answer.*

The magician/scientist went on to explain that magicians refer to the basis for much of their work as dual reality "*what the magician sees and what the audience sees*" - and that there is little difference between magic and everyday science and psychology.

### Concluding remarks

In this section of the report we have provided a flavour of the breadth and depth of the experiences that the Future Brunels engage with as part of their five year programme, a programme that builds on both the attributes of Isambard Kingdom Brunel and the STEM related education and employment opportunities within the wider Bristol area. Within the next section of the report we focus on the Future Brunels views about the programme, drawing on evidence from interviews and questionnaires.



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<sup>7</sup> Matthew Pritchard [www.sciencemagicshows.co.uk](http://www.sciencemagicshows.co.uk), advertises what he offers as follows: Can you discover the sneaky scientific secrets behind the illusions? The show will challenge you to think creatively like a scientist and a magician. Along the way you'll meet some of the most inspiring and imaginative heroes of science and engineering. The interactive show encourages enquiry, using magic tricks to inspire students' imaginative engagement with scientific ideas and technological developments.

# Becoming Future Brunels

## Introduction

One aim of the evaluation was to identify key factors of the programme's activities and social networks that contribute to the development of the Future Brunels and their choice of future education and careers. In order to respond to this aim, we have analysed the focus group interviews with Cohorts 2 and 3 and also drawn on the analysis of individual interviews with Cohort 1 after they had participated in four years of the programme. We have observed the full range of activities within the programme and used our knowledge and experience of these activities both to probe the Future Brunels within the interview situation and to make sense of their responses. This section of the report is organised around the themes that emerged from our analysis of interview data. We start by discussing the ways in which the programme gives the Future Brunels first-hand contact with engineers and scientists and also access to scientific and engineering practices. We then consider how the Future Brunels begin to identify with the wider Great Britain community and the ways in which access to Brunel's drawings and designs plays a role in their emerging understanding of the processes of engineering. We then focus on the Future Brunels' developing confidence and how this relates to them feeling privileged at being part of the programme. Finally we present some of the advice given by the Future Brunels about ways to develop the programme in the future.

## First-hand contact with people and their work



Through the programme the Future Brunels have first-hand contact with scientists, and engineers. To give an example, when they visit Aardman in the second year of the programme they meet engineers and production technologists who explain their own

background and day-to-day work. As we touched on in section 3 above, although Aardman is part of the creative industry sector, many of those who work there have studied STEM related subjects: coding, programming in C with expertise in different operating systems; Linux, Windows, and Mac. The staff use technical language when talking to the Future Brunels, for example:

“We shoot on digital SLRs out of USB into the computer”

“We get raws and put them into the pipeline”

“We don’t use a lot of discharge fluorescent, same amount of light from LEDs, less energy”

The Future Brunels learn that whilst the oldest of the staff have backgrounds and qualifications in electronics, the younger staff have studied mechanical engineering and robotics. For example one of the younger staff explained that he chose to study mathematics and physics for A-level because he enjoyed it and then studied robotics at university because it combined mathematics with his other interests, after which he spent three years working on electronics and mechanics, programming robots. A lighting engineer explained that he had come to Aardman through a sustained interest in working backstage which had led him to working in lighting in West End theatres and that the lighting work he was now involved in with Aardman was very similar to theatre lighting. He showed the Future Brunels how he and his team had combined lights to produce the shadows that were needed for a TV advertisement they were producing. The Future Brunels learned that in the CGI (computer-generated imagery) department the vast majority of staff had studied A-level mathematics, and many had degrees in mathematics or computer science.

### **STEM work experience**

Meeting and talking to people in these workplace visits provokes the Future Brunels to think about their own work experience which is organised by their schools when they are in Year 10. For example one of the Future Brunels explained that after the visit to Aardman she had wondered if she could organise work experience with this company.

Int: Have you started thinking about work experience, or have you got any plans?

G: Yeah well I mean we had an assembly on it today because we have to it’s in May so well I had this mad idea when I was actually it was probably after the Aardman day that I wanted to do work experience at Aardman. So in a way actually Brunel really influenced that because I did think ‘Oh Aardman would be brilliant, like I could go and do work experience there’ but I think it’s very competitive getting to do it. So that would be brilliant, but I don’t think it will

Dad: I would I mean the difficulty is knowing who to...for the kids is knowing who to approach, because they don’t know anybody. And for us I would love to have a list of people that were willing to take Future Brunel people if it fitted for obviously from a timing point of view

In general the workplace visits appear to trigger the Future Brunels to start thinking about organising their own work experience. To put this in context, in the UK, around 93% of young people undertake work experience during their school career, and about 50% of placements are in the summer term of year 10 (age 15–16). There is no fixed model for organising work experience programmes, but schools are expected to lead; typically one teacher takes the role of ‘work placement co-ordinator’, and is tasked with ensuring pupils find a placement. The timing and the numbers involved mean that only a limited amount of effort can be spent finding the ‘ideal’ placement for each pupil, so the tendency is for placements to be with the same companies every year, and for many placements to be obtained via parents’ employers, friends or relations (Hillage et al., 1996, Waller et al., 2004). Meanwhile, employers who may be willing to offer placements lack relationships with schools or experience in setting them up. There is, therefore, a gap into which the Future Brunels programme can step and help the young people it serves by realising potential placements. In response to demonstration of considerable interest in their visits to some of

the workplaces, and enquiries made by the Future Brunels and their families, the programme leads (Gemma Kearsley-Wooler and Rachel Roberts) have facilitated year 10 work placements for some of the young people:

- G: We went to Babcock Engineering. We had an insight of everything they do there, which was really interesting.
- Int: Was that a week?
- B: Yeah. We got to work in every aspect of the business 'cause it was really good.
- Int: Who organised it for you?
- G: Future Brunels.
- B: I think it was a very good work experience compared to what I've heard from my friends, because we literally got to work in every aspect of the business from the engineering of making nuts and bolts to the business side, getting deals and writing a business plan of what we do, various things like that. It gave us a taste of what it would be like to work in those areas.
- Int: They were really serious, then, in that sense?
- B: Yeah, it helped a lot.

Interestingly for one of the Future Brunels his work experience at Babcock made him think that he would prefer to go into the business side of engineering.

- B: If I went into engineering, I think I'd prefer to go into the business side of things. I didn't find the manual work so interesting as I did the business and the science behind it. From going to Babcock as our work experience, it's shown me that I'd rather go into the business side of things, 'cause we got to go round the whole business.

Another Future Brunel was thinking about applying for an apprenticeship at Babcock after her work experience with this engineering firm.

- G: I was thinking of getting an apprenticeship at Babcock in the manual stuff.
- Int: An apprenticeship at Babcock itself. Is that to be an engineer?
- G: To work with making stuff. I thought I would enjoy the design work on the computers, but we did a day on that and I didn't enjoy it as much as that. That led me into the craftwork direction.

From discussion of work experience as part of the Future Brunels programme some of the Future Brunels have developed the confidence to proactively approach potential work experience placements for themselves. For example one Future Brunel contacted Babcock himself.

- B: I emailed and then rang them, and told them about the Future Brunel thing.

Another boy who had always wanted to become a physicist took the initiative to approach the Rutherford Appleton Laboratory in Oxford for work experience.

- B: I wrote an application and I've emailed more than a few people. Miss helped me a bit as well.
- Int: Why did you choose that one?
- B: 'Cause they've got a particle accelerator there.
- Int: Is that what you want to do then?
- B: Roughly, yeah. I find it interesting. I do find particle physics interesting.
- Int: Had you always found that interesting?
- B: Yeah, but a bit more so after the day in Year 8, was it, when we went to Bristol University's physics lab [Quantum Photonics Department] That was fun.

We know from talking to the programme leads that this boy had discussed the idea of approaching the Rutherford Appleton Lab with them.

### The value of first hand contact with adults outside the school environment

We started this section by discussing the importance of the first hand contact that the Future Brunels have with people and their work. We end with emphasising the importance of the Future Brunels relationships with the programme leads. Rachel and Gemma have both studied science at university (chemistry and physics respectively) and are likely to implicitly and intuitively bring their knowledge of science to their work with the Future Brunels. From the focus group interviews it is clear that the Future Brunels value their relationship with Rachel and Gemma and treat them differently from teachers. In this respect Rachel and Gemma are female scientists with whom the Future Brunels can identify.

Int: How important are Gemma and Rachel to the programme, do you think?

G: They know how to help you. You don't feel pressured to talk to them. With teachers, it's a bit awkward talking to them, but with them it's down to earth and you can talk about anything.

Int: Do you think they could help with more advice on possible careers?

G: No, they do a lot already with the careers and stuff. They really try and help you.

Int: In what way, for example?

G: Any offer that comes up for extra trips, they try and contact you, and with all the contacts they've got they've managed to give people work experience placements.....

### Access to scientific and engineering practices



In the previous section we have emphasised how important it is for the Future Brunels to talk to scientists and engineers. It is also important for them to learn about and have access to scientific and engineering practices. As discussed in section 3 Future Brunels visit a wide range of STEM related workplaces. The discussion below about the visit to a sewage treatment works illustrates how such visits provoke them to think about the science and technology behind the processing of sewage.

G: I really weirdly find it really interesting.



Int: Why do you say weirdly?  
 G: Because when you think of it, some people think it's a bit weird but it's sewage and everything but it's really cool how it just changes like into a completely different thing; but I think the whole day, I think some people just find the thought of it a bit not very nice.

Int: And what changes into different things – the sewage?  
 G: The sewage changes into drinkable water and water that we use. So water in our house and we just see how like it's broken down and how it's completely changed.

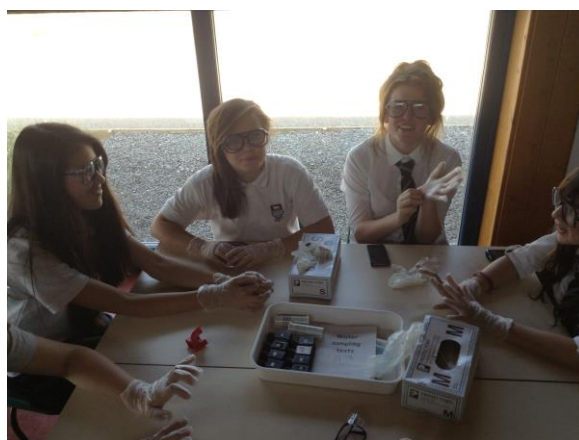
.....

Int: Tell me why you enjoyed it.  
 B: I thought it was a really good way of seeing how something so every day is handled in a scientific way, learning about how they deal with it using bacteria and things like that, which I didn't know previously. I thought it was really interesting.

.....

B: I really enjoyed that day.  
 Int: Tell me why then.  
 B: Well probably it's because like my dad does like a similar sort of job to that and like when I was younger I went to a similar sort of Open Day to work so I already knew a little bit about it. But I just find it like amazing how it can go from something that you flush down the toilet to something that we use every single day.

As the Future Brunels walk around the sewerage plant the whole process of turning household sewerage into environmentally safe treated wastewater is explained to them. The tour of the works included areas where debris, rags and large objects are removed using screens, treated, piled up in skips, and eventually taken away by truck. The Future Brunels saw tanks where the solids sink to the bottom and are removed as sludge. In this treatment works, sewerage is treated biologically - the liquid passes through special media which has bacteria growing on it. The bacteria feeds off the waste, helping to clean the water, and is later killed by UV treatment. Following the tour, Future Brunels put on plastic gloves and carried out water sampling tests. They were asked what they knew about ammonia and nitrates, and about pH, then were asked to make tests on Bottle A – water from the final settlement tank, before microbes are taken out, and Bottle B – from primary settlement tank, with bits in, falling to bottom. Following this was a discussion on nitrates, fertiliser problems, and the implications of nitrogen levels and the value of water treatment.



### **Integrating science and engineering**

The Future Brunels programme aims to provoke an interest in a wide range of science and engineering careers and the programme of activities are sometimes more focused on science, sometimes more focused on engineering and sometimes integrate both. We were interested in whether the students were able to discriminate between science and engineering and were surprised by their responses which showed more awareness of differences than we had anticipated.

Int: What do you think is the difference between science and engineering?  
 B: They can both be hands-on. Engineering is a bit more practical whereas science you have to get an understanding of stuff first before you do stuff with it.



The Future Brunels are aware that some of the activity days have more of a focus on science and others more of a focus on engineering.

G: I think there is definitely some days when it's more science like the pinhole cameras that's more with the chemicals, definitely more science.

However in general they see the activity days as blending both science and engineering, for example the visit to the Suspension Bridge.

Int: Could you name one that's more engineeringy, for example?

G: The Suspension Bridge. That was more engineering.

Int: One that's more sciency you can think of?

B: That one did explain some physics and stuff behind it.

Int: Which was that one?

B: The Suspension Bridge one.

Some of the Future Brunels express a preference for science.

G: I can't speak for everyone who does it, but a lot of us really like science but not necessarily engineering, which I know is what Future Brunels is.

Int: It's both, I think.

G: Yeah. I'm really not very interested in engineering, so as much as I love Future Brunels, those days aren't really particularly appealing to me.

Int: Which ones? The ones that seem like engineering?

G: Yeah, the factory ones where they tell us how the machines work.

However they are aware that the programme needs to appeal to a wide range of interests.

B: I think there's quite a good balance covering engineering and science.

G: There has to be 'cause not everyone's the same as us.

Several Future Brunels told us that they were not very good at making things with their hands, but that they still valued the making and engineering aspects of the programme.

Int: And if you say you're not so happy with doing things with your hands or do you think you're more interested in science than engineering or are there aspects of engineering that interest you?

B: Kind of but the way that the Future Brunel people do it – even though I'm not very good at doing stuff and I think they really support you and really like try and make you do better at it and give you help in stuff that you need, so it makes you, so it still makes you interested in engineering even if you're not that good at using your hands and stuff like that.

We suggest that the blend of engineering and science that threads through the programme, both in terms of the design of the annual modules and the individual activity days (for example the visit the Clifton Suspension Bridge) may be a key element of the programme which distinguishes it from other out-of-school STEM initiatives.

### **Becoming part of the ss Great Britain community**



When the Future Brunels first visit the ss Great Britain they are given badges that are identical to those worn by all employees and volunteers on the ship. They are also given sweatshirts and free passes to visit the ship with their family and friends. We know that this aspect of the induction into the ss Great Britain community is considered to be potentially important by the organisers of the programme. For this reason we probed in the interviews whether the Future Brunels feel part of the ss Great Britain community. Interestingly many

of the Future Brunels spontaneously mentioned their ss Great Britain badges as being important in their response to this questioning.

B: Yes, well I think. I see a difference because we got our little badges and I went round with my Mum – I think it was a couple of months ago – and I wore my badge and I was walking and some little kid pointed out to me because he thought I worked there and he asked me where the toilets was. I was like ‘Oh’ because I knew where and I pointed and he was like ‘thank you’ and that made me feel like I am part of the team because we’ve been places that not that many people’s been before. Like we’ve been underneath – which is actually dangerous, a pretty nasty risk so we could fall on our head, we had to wear like all this healthy safety stuff and it just makes me feel like privileged, big privilege.

G: It’s nice knowing [the ss Great Britain], ‘cause we’ve got our fleeces and badges, and all these little things that link us back to it. It’s nice to have.

Having access to parts of the ship that are not normally available to the general public seems to contribute to the Future Brunels feeling part of the ss Great Britain community.

B: Because we won’t be able to see it behind the scenes if we weren’t part of the programme. The educational trips are very good but that’s an added bonus.

Int: What about you?

B: Yeah, ‘cause they take us on the ship sometimes, they let us tour it and they give us badges. It makes us feel part of it.

.....  
G: You get to visit all the bits that members of the public can’t go into.

Int: Give me an example.

G: We saw the boilers or something.

G: We went into the air cooler thing.

Int: Was that interesting?

G: Yeah, so cool.

Int: Why cool?

G: ‘Cause you don’t think there’s more to the ship. You think you can see everything but you can’t.

The free tickets that give them access to the ship with their family and friends are also important to them.

B: They give us free tickets at the start of each year. Once you go, they stamp them and you come back for free for the rest of the year.

Int: Do you go back quite often?

B: Normally if there are relatives visiting or family friends

G: We sometimes go if there’s people visiting Bristol.

B: Otherwise I feel like I’ve been to the ss Great Britain quite a few times.

G: Yeah. My mum calls it my second home.

The Future Brunels get to know the staff and the volunteers and this also contributes to them feeling that they are part of a community.

G: We’ve made friends with everyone so we all feel like a little community.

G: Like when I’ve been down there before with my mum I’ve like seen a few of them and they’re like oh hello like we know them more.

.....  
B: ..... I also feel like the staff of the ship make it feel like we’re part of the team almost.

Int: In what way? Give me an example.

B: They’re quite welcoming. Almost they treat us like equals more than you might do if you were visiting normally.

G: We have a proper badge.

To summarise the “proper badge”, being treated as equals by the ss Great Britain employees and volunteers and access to parts of the ship that are not normally accessible to the general public all contribute to the Future Brunels feeling that they are part of a community that centres around Isambard Kingdom Brunel and his ship the ss Great Britain. We suggest that this is important in terms of the Future Brunels being able to identify with a community of practice that is linked to the work of Brunel. As the quotations above indicate the Future Brunels feel privileged to have access to parts of the ss Great Britain that are not normally visited by members of the general public. The idea of being privileged is also evident when they talk about the access they have to Brunel’s designs and drawings, as we discuss in the following section.

### **Access to the working practices of Brunel**



From the beginning of the programme each cohort of Future Brunels is taken into the ss Great Britain Trust’s Brunel Institute and introduced to the drawings, sketches and design work of Isambard Kingdom Brunel. Many of the Future Brunels commented on how privileged they felt to be able to study Brunel’s work.

- G: I thought it was really cool 'cause we get to see behind the scenes, we saw his writing when he was designing things, which I thought was really cool. It's special 'cause only we got to see it, because it's behind the scenes.
- G2: Stuff like all the drawings that he's done. If you go down there in the library bit, not many people see all the different stuff that he done when he was younger.
- G3: I really liked going to the archives, 'cause this amazing guy wrote this and drew this. He was an amazing artist.

They are shown the drawings Brunel did as a young boy and are impressed by his skills at drawing from a very young age. They learned that he was mainly self-taught as an artist and that he loved drawing.

B: When he was really young his drawing was at a really high standard. He had a talent, if you know what I mean, to draw like that.

Int: What about you? What have you got to know about...

G4: Yeah, his drawings that he did when he was 10 or so were really good. I think he could draw a perfect circle at a really young age, and his designs that you wouldn't see normally.

B: Because like back in that day they didn't have equipment that we have today and producing something brilliant like that makes us feel like 'wow!' Like in Art we got taught how to like draw and that. I bet he never had that so he's obviously learned himself.....

G: His ideas like developed a lot. Like even when he was younger, he was really talented and did like drawing....

B: Yes when he was about six he could draw like a perfect rocking horse.

The Future Brunels were surprised by the way in which the design for the Suspension Bridge evolved over time and the way in which Brunel made use of rough sketches.

B: I was surprised by things like how different his design for the Suspension Bridge is to the completed work. I find that kind of thing fascinating.

G: I find it interesting seeing the processes he goes through before he gets to the final...

Int: Give me a bit more explanation.

G: You can see all his rough sketches, and that's really interesting.

They also learned that Brunel wasn't always successful with his initial designs and that his original designs for the Suspension Bridge were rejected by the committee.

G: I think he hasn't really – sometimes he didn't like get what he wanted. Maybe he lost something and maybe it didn't go the way he was planning, but he still carried on and he still developed his ideas.

G2: We've seen his plans, and we looked at all his plans and his designs and I remember that time we learnt that he got rejected by the science committee because his suspension bridge was too long we learnt about that.

G3: Like we've seen like all of his potential ideas for the bridge to have something like gargoyles on the top of the bridge

Interestingly when discussing the way in which Brunel was not always successful some of the Future Brunels began to reflect on how they had been chosen to become part of the Programme.



G: Yes like when I started the Future Brunel, when we did the first day, we had to make a rocket car and I didn't do it but because I expressed my ideas they chose me to go on. That was why I was kind of like shocked to become a Future Brunel because I didn't get everything exactly right.

From the interview responses it seems that being able to study Brunel's design work is important for the Future Brunels because they learn about the processes that are involved in producing a piece of engineering, and



in particular the role of sketching, reworking designs and learning from failure. In having access to the processes behind successful engineering projects they are learning that the attributes of success are as much about tenacity and hard work as they are about brilliance. That some of the Future Brunels spontaneously linked their own experiences of designing a rocket car or cardboard bridge when being selected for the Future Brunels programme with what they were beginning to learn about Brunel's way of working could be important in terms of their imagined future identities.

### **Developing confidence and feeling privileged**

Becoming part of the programme seems to have impacted on how the Future Brunels view themselves. This is particularly noticeable for those participants who were not confident about their abilities and potential when they joined the programme.

G: Yes I think everyone does view me different. Even before I started Future Brunels I was interested in science but it's opened so many doors like and it's made me interested in so many different things and I think since I have become a Future Brunel I have been more confident which is actually true but it sounds weird.

Int: Can you explain why?

G: Yes, I used to be really shy and like I didn't really talk a lot but since I started Future Brunels I got into like talking because there's like people from different schools and we also went to Portsmouth for the University and we were like just pushed in with like 200 people in a room and we just had to talk – we just had to and you couldn't back away and not talk to people so I think since I've done it it's given me a lot of confidence.

Int: Oh okay. Does anybody else feel their confidence has changed?

B's: Yes

B: A lot.

Int: Why, why is that then?

B: Because we have to talk in front of a big crowd like the majority of the time so now there were people that I never knew before and never seen before but people would run a school, I've seen them – I've not spoken to them so it's gaining me more confidence speaking to them than some strangers I've never spoken to before.

Int: What about you?

B: You said in like, in the start of the programme when I first got talking it was like, at first I was really shy and I wouldn't speak to anyone but as soon as I started speaking to people, like in a way do you know it's helped my confidence so much because after I have been able to talk to so much things, I've become a lot less shy than I was in the first place.

Int: And can you tell me what it is about the programme then that's helping you with your confidence. What is it?

G: It makes you confident in yourself because there's so many things you learn and there's so many things that other people don't know. Even my parents like I tell them stuff and they're interested and they want to know so I just feel like I have a lot of stuff to tell people and I feel like it makes me more confident.

Within the responses above the three students attributed their developing confidence to learning to work in a team, learning to speak to groups of people who you do not know, and learning "new stuff" that other people do not know.

There is also evidence that being chosen as a Future Brunel provoked them to think more positively about themselves, and in particular their ability to work in a team.

G: I was surprised when I was picked.

Int: Why?

G: 'Cause of the sheer volume of people that were in the selection process.

B: I was surprised I was picked 'cause the final selection, they weren't looking at the [final thing you had to make] in the end, almost, which was what I was expecting. Ours wasn't very good.

Int: Why do you think they picked you? What were they looking for?

B: I think our team worked quite well together compared to some of the other groups.

Some Future Brunels are aware that other students in their science classes are beginning to ask them for help, and this also contributes to their developing confidence.

B: Especially in science. Students, the students in science because I'm in Future Brunels they were all asking for help because in class I think I'm really keen on it and I'm fast and sometimes get it – like the majority of the time and then say we do something that not a lot of people know, they will come up to me and say 'Can I have help, can you help me with this?'

Within some (but not all) of the schools being a Future Brunel had changed the perception of their teachers about them.

G: My science teacher thinks I'm really good at science just because I do it but I'm not.

Int: Why do you say you're not though?

G: I'm ok at science but like he thinks I know all the answers just because I do Future Brunels.

B1: I reckon before [becoming a Future Brunel] they didn't really think much, if you know what I mean. The people that I hang round with and that, they probably don't really think anything, but if you get into Future Brunel they think: he can do something.

B2: .....possibly teachers view us as more gifted and talented, almost, or capable in subjects.

Int: What about you?

G: Yeah, I think it's one of those things that has opened loads of opportunities in school, because when you're picked for something sciency at the end of Year 7, you're miles off doing GCSE science, and I think maybe if I hadn't done Future Brunels I wouldn't be doing Triple Science now and wanting to do A-level and stuff, because you do a little bit more science and you take a bit more interest in it.

One boy had a history of misbehaving at school when he first started on the Future Brunels programme, but over time his confidence in his ability seems to have developed, as had his father's perception of his ability.

B: ...my dad's like every time, say I did something wrong in school, he would look at me, he would know I got it in me that I could be good and I have tried to be good recently because in Year Seven I've never been the best behaved and he would look at me and be like 'I know you can do this because the [Future Brunels] project that you're on' and I think to myself – I'm like these two here – I can do it. It's given us confidence.

In the focus group this particular Future Brunel told us that he is now thinking of becoming a science teacher. He openly talks about how he used to misbehave at school, but now is trying hard to be "good". He says that being part of the programme has given him confidence.

In general the Future Brunels said that their parents were proud that they were part of the programme.

G Yeah, we'll be visiting family that we've haven't seen in a while, and they're like, 'G is a Future Brunel now and she's doing all this and that.' I think showing off a little bit. I don't know, but they seem proud.



- Int: Do they know quite a lot of what you do? When you go home, do you talk to them about it?
- G: Yeah, they ask me how it goes every time I come home.
- Int: What about you?
- B: When I first got in my mum was going around telling everyone, and it's a bit embarrassing. [laughter] She still goes around telling people about Future Brunels now when we go to family greetings and meet-ups.

As the comments above suggest developing confidence seems to relate to your own and other people's awareness of your ability. Furthermore becoming more confident in your ability is likely to be an important aspect of the development of aspirations. Developing confidence seems also to relate to a feeling of being privileged. As discussed earlier the Future Brunels have a sense of pride at having been chosen and a growing pride at being part of the diverse community of Bristolians and other people who have become closely associated with the ss Great Britain and Isambard Kingdom Brunel.

### **Thinking about the design of future programmes**

#### **The importance of "having a go yourself"**

We have asked all of the Future Brunels what they think are the characteristics of a good activity day, and they all tell us that the sessions should be hands-on and interactive. In the focus group interviews we probed further what they meant by this and the following quotation seems to capture the essence of this idea.

- Int: What do you think that means, interactive and hands-on?
- B1: Actually having a go yourself.
- B2: Yeah, and getting to do a lot more stuff rather than having somebody come in to show us things. That's interesting but I think it's more interesting and engaging when you get to have a go at something or you get to see something that's really complex and interesting, but you get to understand it yourself and have a go at doing things.

Interestingly the above quotation links developing an understanding of a complex process with hands-on embodied activity which resonates with an approach to learning that is influenced by the theory of what is called embodied action (Maturana et al., 1987).

All of the Future Brunels were unanimous in their comments about not wanting to listen to people "talking at them" for too long.

- G: We had this one trip where we were listening to a man speak for about an hour and then after that we were just looking at a gallery and then we were listening to another speech for like another half an hour, like we weren't actually doing anything.
- G: After you hear someone talk for so long stuff just stops going in.
- G: And we were all standing for ages as well.
- G: We don't know much about engineering and we don't know much about all that side of stuff so for us to be loaded with loads of engineering facts and we're just don't really.
- G: Sometimes I don't think they really take into account that we don't really know much.

We suggest that the Future Brunels are not saying that people should never "lecture at" them but that it is the balance between hands-on/interactive activity and talk that is important.

#### **Cover a broader range of STEM subjects**

Several Future Brunels told us that they would like the Future Brunels programme to cover a broader range of STEM subjects, including computer programming and mathematics.

- B: Possibly try and cover a broader range of STEM subjects.  
 Int: Like what, for example, is not covered very well?  
 B: Computer science, for example, or maths

The Future Brunels do encounter ideas related to computer programming and mathematical modelling in their conversations with engineers and scientists. However they could be more explicitly part of the programme. For example a visit to the Department of Engineering Mathematics at the University of Bristol could focus on the work of the Bristol Centre for Complexity Science or the Intelligent Systems Research Group.

### A day in the life of a scientist or engineer

One Future Brunel told us how much he appreciated having access to what “a day in the life of a scientist/engineer” might be, and prefers these to being given a tour around a factory

- B: *I think for the younger years it's quite nice to have loads of tours and stuff to broaden their horizons but when you're in Year 10 and 11 you're more deciding what you want to do so it's nicer to have activities and stuff where you get to have a go at certain things to get a better idea of whether or not a certain job or whatever is for you.*

Whereas this Future Brunel appreciated the value of a “tour around a factory” he is suggesting that it is important to begin to understand more about the nature of the science and engineering jobs carried out by people working in industry to inform his future career choices. This seems to relate to his desire to imagine his future as a scientist or an engineer.

We suggest that more of a focus on the people and their work might have been more interesting for the two girls who found the visits to engineering premises repetitious.

- G: Also, the factories, some people know more than others, but generally they're quite similar for us. They tell us about a big machine and to us it looks like another big machine.  
 G Do more interactive days. For example, we just did the forensic science day and the hospital. They're different. You don't get to do that normally. I'm sure factories are brilliant, but not so many factories. Just one.

### Make the selection process more open

Some of the Future Brunels suggested that a more open selection process would be fairer, commenting that teachers at their school had picked the students to take part in the first round of the selection process.

- G: Don't have it aimed toward certain types of people. Have it open for everyone.  
 Int: Everybody in the school?  
 G: Yeah.  
 G: Or have it open to people who's interested in science and engineering.  
 Int: Have more of them, you mean?  
 G: When we were picked it was the teachers picked you, but it should be open to everyone.

Each school participating in the Future Brunels programme had made their own decisions about how to choose students for the first part of the selection process, which may have advantaged particular students.

### Involve more schools

We have already mentioned that the Future Brunels feel privileged to be part of the programme, and they are aware that many young people in Bristol are not having the same opportunities as they are having. This led to a suggestion that more schools should be involved in a future programme.

- G1 I think they should get in one or two more schools.....
- G2 And more people will know about it as well.
- B: Yes, yes because not a lot of people – because when we was on that Portsmouth trip there was a few schools from Bristol and I did ask them and none of them really knew about it.

### Careers advice

We have mentioned that opportunities to find out about different types of engineering through discussions with young engineers employed at Airbus and Babcock seem to have been particularly important for several of the Future Brunels, and that one in particular had been greatly interested in the information given by employees at Airbus, who had given an explanation of the different routes into aerospace engineering, making it clear what the differences were between entry as an apprentice and entry as a graduate apprentice, and the different trajectories that were likely to result in terms of career opportunities and salaries. We believe that this information constitutes what would be expected from a careers advisor, yet has not been available to these young people who so clearly are considering possible careers in engineering and other STEM related employment. Investigating access to careers advice has not been part of the evaluation project, and our picture of what is and what is not available to the Future Brunels through their schools is not clear. The Future Brunels project has clearly made a difference to some of the young people involved by giving access to relevant careers information in the course of some of the activities and visits.



## Do the Future Brunels want to pursue STEM-related careers?

### Imagined STEM Futures

The first cohort of Future Brunels took their GCSE examinations in June 2015, graduated from the programme in July 2015 and progressed to post -16 courses in September 2015. The second Cohort will complete the programme in July 2016 and the third Cohort in July 2017. Within Tables 5.1a, b, c we compare what each of the three cohorts told us about their thoughts about future careers when they joined the programme with what they told us in 2015 when they filled in questionnaires and participated in focus group interviews. We also have information about the Future Brunels actual A-level choices (Cohort 1) and ideas about A-level choices from the questionnaire responses and this information is also presented in Table 5.1a, b, c.

When comparing the Future Brunels' ideas about future careers in June 2015 (Cohort 1) and late 2015 (Cohort 2 and 3), with their ideas when they started the programme it is clear that for many there has been a shift in what they state as their imagined future careers. All of the first three cohorts of the Future Brunels are either thinking about STEM-related careers or are keeping their options open by choosing to study a selection of science A-levels.

Analysis of the data suggests that the programme is having an impact on whether or not these young people want to pursue STEM related careers. At the beginning of the programme just over half of the Future Brunels from across the first three cohorts had not chosen STEM- related careers or were unsure about their future careers. By the end of the programme all of the first three cohorts of the Future Brunels are either thinking about STEM-related careers or are keeping their options open by choosing to study a selection of science A-levels. In this respect we consider that the Future Brunels programme is achieving its aim of inspiring young people to explore careers in science, technology, engineering and mathematics.

From the interviews we are able to see which of the range of activities offered by the programme appear to have triggered the Future Brunels interests and expanded their awareness of future possible careers. For example the visit to Southmead Hospital and the Crime Scene House at the University of the West of England seem to have been important for some of the Future Brunels. Opportunities to find out about different types of engineering through discussions with young engineers seem to have been particularly important for three girls in Cohort 3, who are all now thinking about careers in engineering.

Whilst it is not possible to ascertain how interests develop and choices are made, we do know that identity and imagined future identity is highly significant for the choices young people make about their future education and careers. From the analysis of the shifts in ideas about future careers together with the A-level choices we have developed the following set of categories which enable us to further make sense of the data: from non-STEM to a STEM focus; from no clear idea to a STEM focus; developing a clearer sense of which STEM-related career to pursue; overlaying STEM onto original interests; choosing A-level subjects that keep options open. In the following sections we present vignettes to illustrate each of the categories discussed above and discussing whether and how these shifts might be related to the Future Brunels programme.

## The ideas and eventual choices of Future Brunels in Cohort 1

	Ideas aged 12/13	Ideas aged 15/16	A-level choices
<b>Cotham School</b>			
S1	Law	Journalism	Biology, English Literature, History, Mathematics
S2	Teaching	Teaching or working with people	Art, Chemistry, English Literature, French
S3	Music/maths	Unsure	Biology, Chemistry, Geography, Mathematics
<b>Redland Green School</b>			
S4	Unsure	Music software developer	Computing, Mathematics, Music Tech, Physics
S5	Unsure	Sports coaching/sports science	Biology, Chemistry, Mathematics, PE
S6	Architecture / Product design	Acting, writing or computers	Drama, English Literature, Mathematics, Further Mathematics, Physics
<b>Bedminster Down School</b>			
S7	Law	Aeronautical engineering	Accounting, Chemistry, Mathematics, Physics
S8	Formula one driver or mechanic	RAF apprentice	(RAF apprenticeship)
S9	Drama	Criminal Psychologist	English Literature, History, Music, Physics
<b>Merchants' Academy</b>			
S10	Accountant or banker	Accountant or businessperson	Business Studies, History, Mathematics, Physics
S11	Vet or nurse	Businessperson or Something to do with Biology	Biology, Business Studies, Mathematics, Psychology
S12	Fashion designer	Forensic science	Chemistry, Biology, Mathematics, Physics

**Figure 5 a The ideas and eventual choices of Future Brunels in Cohort 1**

## The ideas of Future Brunels in Cohort 2

	Ideas aged 12/13	Ideas aged 14/15	Ideas for A-level subjects
<b>Cotham School</b>			
S13	Politics	Computers	Computing, German, Mathematics, Further Mathematics, Physics
S14	Teacher/something to do with science	Biochemistry	Geography, German, Biology, History, Mathematics
S15	Working with animals	Midwife, nursing, or working with animals	Biology, Chemistry, Psychology, English Literature
<b>Redland Green School</b>			
S16	Engineer	Chemist	Chemistry and others
S17	Engineer	Geology, Geography	Not given
S18	Engineer	Doctor/engineer/biochemist	Biology, Chemistry, D&T, Mathematics, Music
<b>Bedminster Down School</b>			
S19	Unsure	Unsure	Creative writing, Graphic communication, Product design
S20	Theoretical physicist or geological technician	Computer Scientist	ICT and other subjects
S21	Not known	Not known	Maths, Further Maths, Law, Economics
<b>Merchants' Academy</b>			
S22	Drama	Journalist/Media/Drama	English, Drama, History
S23	Sport	Zoologist	Biology, Chemistry Spanish, B-tech sport
S24	Unsure	Unsure	Chemistry, possibly Computing Media Studies, Mathematics

Figure 5 b The ideas of Future Brunels in Cohort 2

## The ideas of Future Brunels in Cohort 3

	Ideas aged 12/13	Ideas aged 13/14	Ideas for A-level subjects
<b>Cotham School</b>			
S25	Game developer	Something to do with Computers	Computing, Mathematics
S26	Drama	Science and Maths or Dance	Biology, Chemistry, Geography/Dance, Mathematics
S27	Doctor/dance	Dentistry	Biology, Chemistry, Mathematics
<b>Redland Green School</b>			
S28	Sports coach/PE teacher	Physiotherapist	Not sure
S29	Technology	Art/set design	Art, Biology, Mathematics, Physics
S30	Astrophysicist	Particle physicist	Chemistry, Maths, Further Maths, Physics
<b>Bedminster Down School</b>			
S31	Sports Science	Marine Engineer Officer	Science, Engineering, D&T
S32	Accountancy or marketing	Computer Engineering and Coding	Computing, Science
S33	Not known	Maths and Science	Maths, Science
<b>Merchants' Academy</b>			
S34	Singer	Manufacturing or design engineer	Engineering, Music, Science
S35	Not known	Teacher	ICT, Maths, Science
S36	Not known	Science or sports teacher	History and others

Figure 5 c The ideas of Future Brunels in Cohort 3



## **From non-STEM to a STEM focus**

### **Example 1: from fashion designer to forensic scientist**

During year 8 and in her first months as a Future Brunel, Jo said that she would like to be a fashion designer. She read fashion magazines and catalogues and when younger, used to spend her pocket money on an online 'fashion and dress up games community'. At age 13 the resources that Jo relied on to furnish her imagined future in fashion design were drawn from the media and experiences she had at hand in her domestic environment – a 'star dolls' dress-up magazine she had had when younger, and the Matalan mail-order catalogue. At that time, she supposed that the steps to take to becoming a fashion designer would be to do well at school and get good grades, and then go to college. She was unaware where the colleges might be or what courses were available at her local college, where she thought she might go.

Three years later, Jo was taking five GCSEs in English Literature and Language, Core and Additional Science, and Mathematics, and two BTECs in Childcare and in Travel and Tourism. When Jo filled in a questionnaire at the end of the year in which she had completed her GCSEs, she stated that she was going to St Brendan's Sixth Form College to study Physics, Chemistry, Biology and Mathematics at A-level. This was because she was interested in each of these subjects and needed them for her now chosen future career of Forensic Science and was planning to study Forensic Science at University. We suggest that the Future Brunels programme has given Jo the resources to develop a new imagined future as a forensic scientist and to elaborate that idea; and we may reasonably attribute it at least in part to the cohort's visit to the "Crime Scene House" at the University of the West of England.<sup>8</sup>

### **Example 2: from law to aeronautical engineering**

When interviewed at the beginning of the Future Brunels programme Brad had told us that he was interested in law because he knew something about it through his mother, who was working as a legal secretary. Brad had been particularly interested in the information given by employees at Airbus, during a visit when he was aged 14-15, who had given an explanation of the different routes into aerospace engineering. They had made it clear what the differences were between entry as an apprentice and entry as a higher apprentice and as a graduate, and the different trajectories that were likely to result in terms of career opportunities and salaries.

In year 11, Brad took nine GCSEs: English Literature and Language, Mathematics, Triple Science, History, French, and Design and Technology (Resistant Materials), and said that he would also like to have studied Spanish and Engineering. By the end of his GCSE year, Brad had chosen to attend St Brendan's Sixth Form College and was planning to study Mathematics, Physics, Chemistry and Accounting at A-level, with a view to entering Aeronautical Engineering for a Higher Level Apprenticeship. Interestingly by the time Brad was 16 his brother had started a post-16 apprenticeship in North Bristol at a specialist college, and this is also likely to have influenced his choice of future career.

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<sup>8</sup> This is a specially modified 'house' that can be adapted to mimic the conditions typically found at a variety of crime scenes. Forensics experts at UWE can create complex simulated scenarios Perspex wall coverings and removable floor tiles allow the introduction and removal of critical evidence such as blood splatters. Students get a taste of what they would encounter as a Forensics professional following a burglary, murder, child abduction etc. There is CCTV and two-way communication in all the rooms, along with a control suite so feedback can be given. (source: <http://www1.uwe.ac.uk/whyuwe/fantasticfacilities/crimescenehouse.aspx>)

### Example 3: from singing to engineering

When we first interviewed Anna she told us that in the future she was thinking about ‘maybe singing or something like that’ and she explained how involvement in music and performance had helped her develop an identity as a confident and able person:

- Anna Yeah. I do like a lot of music stuff in school. Like the first time when I came into Year 7 I was really shy, and then I did a music thing and that’s how like I became more confident.
- Mother Talent show.
- Anna Yeah a talent show. And I won it and I felt like quite happy with myself, so I’ve just been doing music a lot now.
- Mother And do you do any instruments or is it mainly singing?
- Anna Piano.
- Int Really?
- Anna And I want to learn the guitar because I’ve got a guitar but I don’t know how to play it yet.
- Int And where do you learn the piano then?
- Anna At school.
- Int Oh right.
- Mother You’ve done a performance.
- Anna Yeah I’ve done lots of performances and like plays at school. (...) I’ve done like ... I don’t know what it was called but it was like another thing where loads of people came and we did like loads of music and it was quite good.
- Int Okay. And then you say you make it up, do you make up songs, or do you...
- Anna Yeah like lyrics and ...
- Int Do you write those down then?
- Anna Yeah I use Garage Band on my iPad to do some like actual music.
- Int Okay. Were you doing that before you had the iPad, or was it with the iPad that you got from the Future Brunels?
- Anna I’ve got a keyboard, and I have been doing some on there. But when I got the iPad I’ve been using Garage Band
- Int Okay, so that means you compose and stuff is it?
- Anna Yeah.

Two years later when interviewed in a focus group interview at school Anna said that she wanted to be an engineer. She said that she wasn’t aware of engineering before but, *‘I’ve become so interested in it and I talk to my mum about it, and I want to do something with engineering.’* She went on to explain, *‘There’s mechanical, civil...’* At this stage, she was studying Core and Additional science GCSE subjects, but another year remains before she chooses A-levels, at which stage it will be possible to say more about the influence of the programme. What is clear is that this young woman is gaining from the widening of horizons that the Future Brunels programme offers.

- Anna I wasn’t aware of like engineering before I started at Future Brunel but since I have I’ve been so interested in it. I was talking to my mum about it as well and I’ve been really into it and I think I want to do something to do with engineering because I’ve got work experience at Babcock.
- Int: Who’s helped you with that?
- Anna Gemma. And I don’t know exactly what I want to be but I’ve always been interested in music as well so I’m not sure but lately it’s been more engineering.
- Int: Okay and you didn’t before you started being at Future Brunel?
- Anna I didn’t know what engineering was.
- Int: And you did start to talk to me about the different types of engineering, what are they?
- Anna Civil Engineering, Mechanical, Design and I don’t know because I’m kind of interested in all of them.

## From no clear idea to a STEM focus

### Example 4: from no idea to being a science teacher

When first interviewed, Julian did not express ideas about the future, preferring to discuss his pride in having been chosen to be a Future Brunel. He said he had a sense of confidence in himself and that this had led him to being chosen to be a Future Brunel: *if like something's coming up and they need someone I'll be there. ... I'm confident and I try, and like I enjoy what I have to do on the trips... it's amazing like the opportunities I'll get.* Julian was keen to point out that the Future Brunels gave him a sense that he was trusted: *At school you get set a piece of work and we do it and then we get set more work. It's just like ... we try to do different stuff, and then the teachers sometimes don't trust us. But at the Future Brunel project they just ... they know that we're capable of doing it.*

After a year in the project he had chosen GCSE subjects in English, Maths, Core and Additional Science, History, Spanish, Drama and Construction. By the end of year 9 and after two years as a Future Brunel he told us he thought he might become a science teacher: *First I need to get my five A-C's for whatever I want to do and then I'm going to get advice from our teachers around the school, and then when I get my final decision – either drama or science I will decide about that but then I think I'll go to University and do my like four year training to be a teacher.*

## Developing a clearer sense about which STEM-related career to pursue

### Example 5: from being an astrophysicist to being a particle physicist

Alf was already very interested in science when he joined the programme, read widely in his spare time, and had become very interested in coding (computer programming). When first interviewed he said that he wanted to be an astrophysicist:

Alf: Not sure. I really like ... I don't know, I'd like to be like an astrophysicist someday. Cos that's quite interesting, but I'm not sure really. It's kind of weird cos a while ago I wanted to be an astrophysicist and like particle physics and all of that, just strange theories. It really interested me and I was like thinking about that, but ... I don't really know. I'd like to do something like quite science based, but I'm not sure at the moment. Cos there are like so many things you can do. But I'm sure like coding, computing, would be quite useful.

A year later, when interviewed as part of the focus group at his school, he explained that the Future Brunels programme was helping him to think through the options that were likely to be available to him.

Alf: I said not necessarily changed the way I think of myself but what I might think of doing when I'm older. I do think I know what I would do when I'm older but it has caused me to question: do I really want to be going into that or that job? That doesn't seem as fun as this, that doesn't seem as interesting. It's also given me a bit of a wider experience of science.

## Overlaying STEM onto original interests

### Example 6: from sport to physiotherapy

In year 8, interviewed at home, Dan said: *Well, if you like football then you obviously always want to be like a professional football player. Or I would like to be some sort of sports coach, either like a PE teacher or ... something sporty, or something to do with science of engineering.* The GCSE courses he later took up were Maths, English, Triple Science and RE, all of which were compulsory, and he chose PE, French and History as options. Responding to questions in a questionnaire two years later, Dan said: *I want to study physiotherapy as I am interested in the human body, and I am doing PE and Biology GCSE, so this will help me when trying to find a job in that area, if I get good results.* For his imagined future at age 25 he said: *I would like to be in a job around the area of physiotherapy.*

- Dan: I'm happy to be a part of (the Future Brunels programme) because you get loads of experiences you otherwise wouldn't really know about or even experience. I've always considered doing something around sport science. I tried to get work experience with a physiotherapist but I couldn't in the end so I got it with this sports coaching team. They have a physio on the team and he said he could give me some sessions 'cause I do want to go into that sport science type sector.
- Int: Have you always wanted to do that?
- Dan: I wanted to do something in sport but Future Brunels, 'cause we've done all the different days and some things have been similar, it has kind of affected me.
- Int: Explain more how it's affected you then.
- Dan: The experience of doing the things and being a part of it. I can't really explain it. It's just good to be a part of overall programme.

## **Choosing A-level science subjects that keep options open**

### **Example 7: from no clear idea to choosing STEM A-levels**

In year 8 Katie said that she loved reading and music, explaining that her ideas had gone from being an author or an illustrator, to thinking about music, but that she might also be interested in something that involved mathematics. Two years later she was thinking about choosing science subjects for the sixth form, on the basis that it would keep her options open. Katie went on to take GCSEs in thirteen subjects; Mathematics, Statistics, Triple Science, English language and literature, German, Geography, History, Music, Religious Studies and PSHE. By this stage she had chosen to attend North Bristol Post 16 Centre where she would study Mathematics, Chemistry, Biology, Geography and Global Perspectives & Research at A-level and intended to go on to university, expecting to become more clear about what course she would take as time went on.

## **Careers in science and engineering**

The overall aim of the Future Brunels programme is to inspire young people to explore careers in science, technology, engineering, mathematics (STEM) and related areas. The team responsible for designing and running the programme value all pathways into STEM careers, including apprenticeship routes and graduate pathways. The Future Brunels meet both graduate engineers and those who have trained through an apprenticeship route during their industry-based activity days.

Within the previous section we have discussed the range of STEM related careers that the Future Brunels are beginning to consider. All of the first three cohorts of Future Brunels are either thinking about STEM related careers or are keeping their options open by choosing to study a selection of science-related A-levels. In this respect it is likely that they will bring scientific interest and understanding to any career that they choose.

The majority (70%) of the first three cohorts of Future Brunels have shifted towards considering STEM related education and careers through participating in the programme. Such a shift is illustrated by the case of Jo discussed in section 5.2 above. When she joined the programme Jo was thinking about becoming a fashion designer. When she graduated from the programme she was planning to become a forensic scientist and she explicitly attributed this to the visit to the "Crime Scene House" at the University of the West of England.

The vast majority are intending to progress to Higher Education, although several of them have discussed taking up a Higher Level Apprenticeship when they finish their A-level courses. By the end of their participation in the project one Cohort 1 Future Brunel aimed to enrol in an A-level 3 RAF apprenticeship and one Cohort 2 Future Brunel was thinking about following A-level 3 Apprenticeship at Babcock.

## Are the Future Brunels able to pursue STEM-related careers?

### Introduction

The underlying approach to the evaluation was that young people's attitudes, knowledge and skills develop as they participate in a variety of communities and practices both within and out of school, that a young person's identity within such communities and practices is relevant both to what and how he or she learns, and that participation in different communities informs the range of potential identities that a young person imagines for him or herself. In section 2.6 we touched on the work of the ASPIRES project, a body of UK research that discusses the presence, within the family, of a range of resources they term 'science capital', science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g. knowing someone who works in a science-related job.) Taking a similar approach in our evaluation, we collected information from the families of the Future Brunels about the range of potential identities available through social contacts and about other matters such as science-related qualifications, understanding, knowledge about science and 'how it works. Here we set out the resources that constitute 'science capital' in the families of Future Brunels. This is followed by a discussion of what is available and/or necessary for following up and developing interests, in other words, the support for and access to gaining the educational qualifications that will enable young people to progress towards STEM related occupations.

### Becoming interested: families and the resourcing of imagined STEM futures

With the question "what is the range of potential identities available to the young person" in mind, we surveyed the range of occupations amongst the parents of Future Brunels and set this against information for the local geographic areas in which they were growing up. In section 6.2.1 the family information for each of the three cohorts is summarised followed by a summary of data taken from the Census, focussing, in each case, on STEM related occupations and on further education with respect to those occupations.

We also collected information on out-of-school hobbies and interests, and the variety and patterns of leisure activities amongst the Future Brunels are described in section 6.2.2, drawing out the informal support in the home that may be relevant to STEM related interests, identities and aspirations.

### Occupation of parents – STEM- related jobs

Amongst each cohort there were young people for whom both parents had studied STEM subjects at university and were working in STEM related professions, and there were also families in which there was little equivalent experience. For some families there were rich examples from grandparents or older siblings. The description of the makeup of each cohort is given below.

For Cohort 1, one quarter (that is, 6 out of 24) of either parent of the Future Brunels are in employment that requires qualifications in science or mathematics (this includes medicine, mathematical modelling, dentistry, computer programming), with the majority of these being fathers. One third (that is, 8 out of 24) of either parent of the Future Brunels were in employment that involves the use of mathematics or application of scientific principles (this includes primary school teacher, specialised tradesperson, bank clerk). Again, the majority of these are fathers.

In Cohort 2, three Future Brunels came from families in which both parents had studied science subjects to degree level or further (medicine, chemistry, pharmacy, computer science), and were working in medicine, academia or in technical professions. For two Future Brunels, both parents had gone to university and studied non-science subjects (law, economics, geography, languages) and were working in professional jobs in Law, Human



Resources, and Education. In another family, one parent had studied to A-level, the other had taken a degree in Humanities and both had made successful careers in arts-based and entrepreneurial activities. Two Future Brunels came from families in which the fathers had continued to study after school on day release or apprenticeship schemes. One had qualified and was working as engineer, the other a surveyor. In both these families, mothers had left school at 16 and gone into administrative work. All three of these Future Brunels had grandparents who were high achievers in their fields (engineering, running successful businesses, and one grandparent was a research scientist).

In Cohort 3, just over a quarter (that is, 7 out of 24) of either parent of the Future Brunels in Cohort 3 were in employment that requires qualifications in science or mathematics (which included parents working in engineering consultancy, defence engineering, financial services, or in the medical profession as doctors or dentists). In three families, both parents had studied sciences and mathematics at A-level. The same proportion (again, 7 out of 24) of either parent of the Future Brunels in this cohort were in employment that involves the use of mathematics or application of scientific principles (to be more specific, these parents had not studied science or mathematics at school after the age of 16 but were working in jobs which required them to handle figures, data, and materials; three were in managerial positions in the retail sector, advertising and publicity, one was a service delivery engineer, and three were running small businesses which involved a technical element such as carpentry and also dealing with accounts and VAT returns).

Overall the Future Brunels with parents in professional jobs whether STEM related (medicine, mathematical modelling, dentistry, computer programming, engineering consultancy, defence engineering, financial services) or non-STEM related (law, economics, geography, languages) were living in the north part of Bristol, and those whose parents had not studied after the age of 16 or who had qualifications gained through workplace training or 'day release' to college while working, were living in South Bristol. This is consistent with the general geographic distribution of qualifications and employment. The following Figures from the resource [www.datashine.org.uk](http://www.datashine.org.uk) and which plots census data show the difference in distribution.

Amongst the parents of Future Brunels in both parts of the city there are people working in STEM related jobs. In the southern part of the city the STEM related jobs that parents were doing (including those whose work is described as engineering) would fall under the heading Employment In Skilled Trades (see Figure 4 below) and in the northern part of the city, the STEM related employment is as Engineering Professionals (see Figure 5 below). The images show that the adults involved in STEM that the Future Brunels in the two areas might encounter through local networks are likely to represent very different kinds of employment

Locations of the homes of Future Brunels in Cohorts 1, 2 and 3

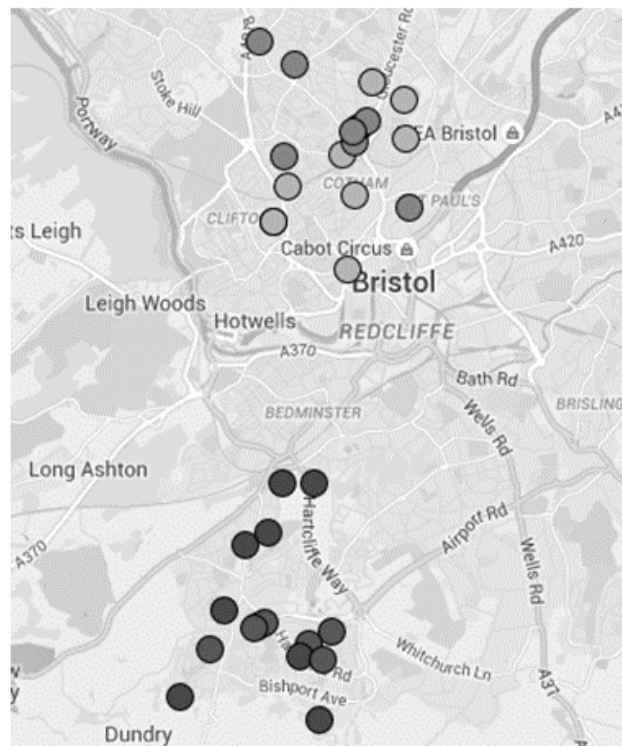


Figure 6.1 The locations of homes of Future Brunels in Cohorts 1, 2 and 3

Information from Census 2011. Employment in Skilled trades: includes Metal Forming, Welding Metal Machining, Fitting and Instrument Making Trades, Vehicle Trades, Electrical and Electronic Trades (*Standard Occupational Classification 52*)

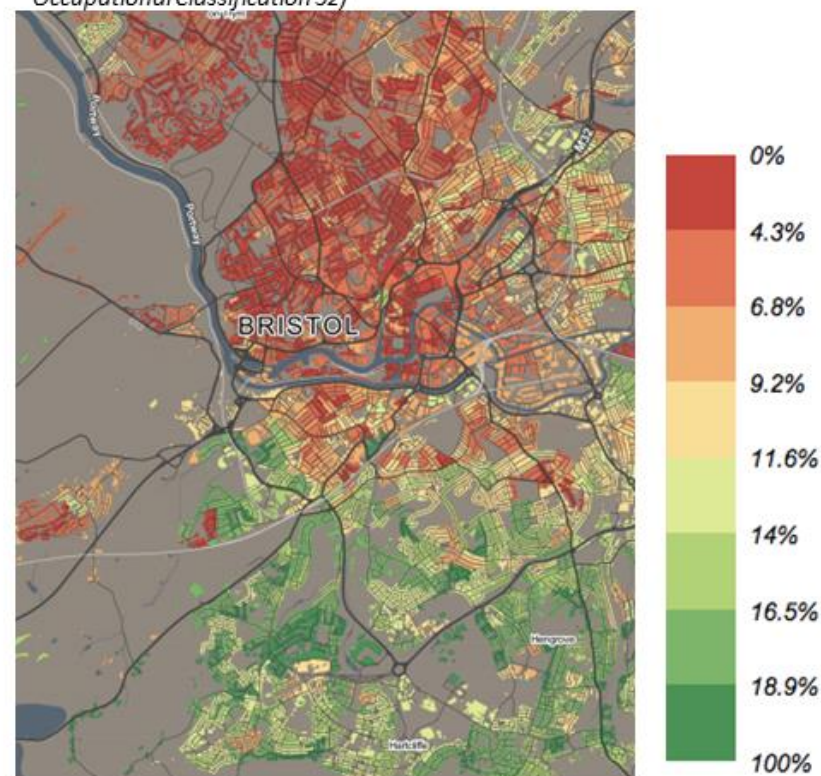
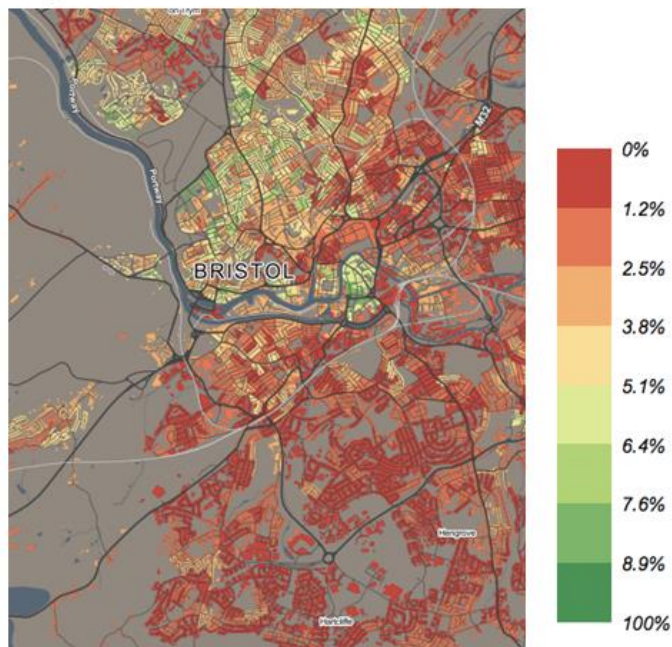


Figure 6.2 Distribution of Employment in Skilled Trades

Information from Census 2011. Employment as  
 Engineering professionals: Civil engineers Mechanical  
 engineers Electrical engineers Electronics engineers  
 Design and development engineers Production and  
 process engineers (*Standard Occupational Classification*  
 212)



**Figure 6.3 Distribution of Employment as Engineering Professionals**

### Out-of-school STEM-related activities

Currently in the UK (as in the USA and other parts of the world) there are signs of a growing interest in making things for their own sake, which some see as aligned with *the fine British tradition of amateurism and the democratisation of skill* (Miller, 2011). Alongside this runs a belief that making and engagement with materials is a means through which learning can be supported, and this has been applied and further studied particularly in relation to the learning of science and mathematical concepts (e.g. Papert, 1993). We suggest that involvement in collecting, designing, making things, fixing or building things may be out-of-school activities through which young people's interest in STEM and science careers might be inspired.

In the course of our interviews with families, it was notable that many Future Brunels enjoy making, fixing and designing as leisure activities, and we noticed a pattern: within some families there was a very high level of making and designing, shared amongst all family members, whereas in others there was a high level of engagement in football, swimming, dance and singing, activities that took place outside the home. Amongst the families in which there was a high degree of making or fixing, many described buying or collecting craft materials for their children. Examples of things that had been made included three-dimensional pop-up cards, models with cardboard, fabric and so on, tie dyeing, painting miniature models, making soft toys and clothes for dolls. Some Future Brunels had been involved in hands-on projects such as making a rabbit hutch, and more explicitly science and technology related projects included finding out how old watches work, making a trebuchet using wooden spoon, and making a theremin (an electronic musical instrument) with a father in response to a music homework project which asked children to make a musical instrument. Many talked about enjoying using the Minecraft app, which allows the building of three dimensional worlds. Minecraft is one of the apps provided for Future Brunels' iPads. Amongst the Future Brunels in Cohorts 2 and 3, three had a strong interest in coding (computer programming) as a self-initiated and self-supported activity.

In some families, there were many activities taking place after school and weekends, so much so that it was sometimes difficult to fit in an interview. For example, many were learning musical instruments, and a high proportion were participating in organised sport outside school. Several were playing their chosen sports at a high competitive level (county or national levels).

We are, of course, unable to track the development of interests and identity through the various activities that the Future Brunels take part in, whether at home, school or through the programme. However, our survey of the informal activities that these young people engage in at home helps to paint a broader picture of the resources that are available to them to support interests and abilities in creating, inventing, designing, and working in teams, all of which are certainly relevant to occupations in engineering, as discussed in section 2, and are very likely to be relevant to other STEM related occupations. It is clear that amongst some families there is considerable *explicit* support for science-related projects and skills that are likely to be relevant to employment, and in others, activities that support the development of skills and interests is present, but the links are not made explicit.

### Following up and developing interests: resources that can help to realise ambitions in STEM

Our interviews and focus group discussions with Future Brunels indicate that most want to study at university after their post-16 courses, with some young people also interested in apprenticeships. Whereas in the past it might have been possible to become an apprentice without qualifications gained from school, families where previous generations had entered STEM related occupations through this route were well aware that the current landscape for young people means that educational qualifications are increasingly necessary and that university degrees are an option that may be relevant to their sons and daughters. In this section we consider the availability of role models in the sense of informal contact with

people who have continued into Higher Education, and then discuss the GCSE qualifications that facilitate access to H.E. and then in section 0 we look at school data that gives an indication of the extent of take-up of STEM subjects amongst the peer groups of the Future Brunels, and of achievement in those subjects. In section 0 we return to the Future Brunels post-16 choices, which were discussed in section 5, but this time discussing some of the points made by the young people during the focus group interviews.

### Experience of Higher Education from family and friends

We have commented in previous reports that some Future Brunels are growing up in families that include potential models for continuing in higher education and a source of informal information about life as a student. The statistics published by Higher Education Funding Council for England (HEFCE) on the geographical distribution of adults who have participated in Higher Education make it clear that there are striking differences between areas of the city. The Future Brunels come from two geographically distinct areas, one in which there is a high rate of participation in HE, implying that potential role models with respect to study after school and sources of information about college and university are likely to be available from other adults in their neighbourhood (for example, the parents of their school friends). The converse is true for young people growing up in other areas, in which, sources of informal information about life as a student and models for continuing in education are likely to be less frequently encountered in the course of everyday life.

Future Brunels from South Bristol schools are very unlikely to have parents or extended family who have studied at University. By contrast Future Brunels from North Bristol schools are very likely to have parents who have studied at University. For example no members of the immediate family of the South Bristol students had attended Higher Education when they left school. This is important because a potential constraint to continuing into Higher Education is the extent of familiarity with what it means to be a student and the nature of student life, and a confidence that spending more years in education (rather than beginning to earn a salary straight after school) is worthwhile. Although schools and colleges provide advice and information about the possibilities, benefits and practicalities of participation in Higher Education, for most students the most easily accessible source of information is from family and friends. Using the postcode of the family home it is possible to access information about participation in Higher Education for the local neighbourhood, or, more precisely, the population of the electoral ward in which the home is situated. A measure of participation devised by the Higher Education Funding Council for England, POLAR<sup>9</sup>, draws on data provided by the Higher Education Statistics Agency, the Learning and Skills Council, the Universities and Colleges Admissions Service, the other UK funding bodies and HM Revenue & Customs. Wards are rated in five quintile groups, ordered from '1' (those wards with the lowest participation in higher education) to '5' (those wards with the highest participation), each representing twenty per cent of the UK young cohort. Six of the twelve Future Brunels in the first cohort live in wards which fall in quintile 5 (highest participation in Higher Education), while six live in wards in quintile 1 (lowest participation). The young people in the latter group would fall in the category of *non-traditional student*, the target group for schemes for Widening Participation in Higher Education institutions. The young people who live in wards which fall in the highest quintile are students at Redland Green and Cotham Schools; those who live in wards in the lowest quintile are students at Bedminster Down and Merchants' Academy.

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<sup>9</sup> The participation of local areas (POLAR) classification groups areas across the UK based on the proportion of the young population that participates in higher education (HE). For more information see <http://www.hefce.ac.uk/analysis/yp/POLAR/>



## GCSE/Level 2 qualifications

The four schools that the Future Brunels attend differ from one another in the patterns of student take-up and achievement in science and mathematics subjects. The following statistics are taken from the government's Department for Education performance tables. Note that performance data are currently organised with respect to a combination of subjects (English, Mathematics, History or Geography, the Sciences, and a Language) known as the English Baccalaureate. In the performance tables, achievement is classified as gaining A\* to C in each subject. Achievement in the 'science area' of the EBacc is achieved through one of the following:

- get an A\* to C in core and additional science GCSE (in core and additional science, pupils take 2 modules in each of the 3 main sciences: biology, chemistry and physics)
- take 3 single sciences at GCSE and get an A\* to C in at least 2 of them (the single sciences are biology, chemistry, computer science and physics)
- get A\* to C in GCSE science double award (in science double award, pupils take 2GCSE exams that cover the 3 main sciences: biology, chemistry and physics)

	Schools in South Bristol		Schools in North Bristol	
	Bedminster Down School	Merchants' Academy	Cotham School	Redland Green School
Percentage of pupils achieving the English Baccalaureate <b>Maths</b> subject area	54%	60%	84%	93%
Percentage of pupils achieving the English Baccalaureate <b>Science</b> subject area	54%	64%	79%	96%
Number of pupils achieving the English Baccalaureate <b>Maths</b> subject area	82	75	155	173
Number of pupils achieving the English Baccalaureate <b>Science</b>	65	45	126	162

**Figure 6.4 Achievement in science and mathematics examinations in the Future Brunels' schools: percentages of pupils and actual numbers of pupils achieving benchmark grades in 2014.**

Good grades in mathematics at GCSE level are necessary for further study of mathematics, science and engineering; poor attainment may rule out the possibility of further study of STEM-related subjects at both post-16 and Higher Education levels. While it is clearly possible for a student from any of the four schools to achieve good grades in mathematics and science at GCSE level, and continue studying STEM subjects after the age of 16, the GCSE performance data for the schools gives us an idea of the proportion of a Future Brunel's peer group that could readily progress to STEM courses post-16, should they choose to pursue that direction. We can therefore make a tentative assumption that the students at some schools see fewer examples of people in older year groups going forward to take up STEM courses post-16 and that they may be engaged in less informal discussion about the nature of such courses and related opportunities.

## Future Brunels post-16 educational choices

For those students who achieve the necessary grades in mathematics and science at GCSE level, the opportunities for further study (at A, AS level or equivalent) are unevenly distributed across the City of Bristol. Students may continue into post-16 education in their own school (if there is a sixth form), move to a sixth form at another school, or enrol in a sixth form centre or college. However there is variation in provision between the South Bristol and North Bristol schools.

Both Cotham and Redland Green schools have well established sixth forms. Currently they both operate within the North Bristol post 16 centre which offers over 30 A and AS subjects. A variety of other options for post 16 education exists within travelling distance (examples are City of Bristol College, Colston Girls' School, and the Bristol Cathedral Choir School).

Merchants' Academy opened a sixth form in 2008 and currently offers A-levels in Art, Biology, Business Skills, Chemistry, Computer Science, Drama and Theatre Studies, English Literature, Geography, History, Mathematics, Media Studies, Music Technology, PE, Physics, Product Design, Religious Studies, Sociology, Spanish, and Textiles. Bedminster Down School has no sixth form, and students must continue their education in another institution. Students from Bedminster Down tend to choose courses at St Mary Redcliffe and Temple Sixth Form, St Brendan's Sixth Form College or the City of Bristol College.

In the focus group interviews there was some evidence that Future Brunels from the South Bristol schools were less sure about their options post-16. For example one of the Future Brunels from a South Bristol school is thinking about becoming a drama or science teacher. He knows that he has to obtain five good GCSEs in order to progress to A-level courses, but from the interview response it appears that he is not yet thinking much beyond this qualification level.

- B: I want to be a teacher but I either want to be a drama or a science teacher.  
Int: Okay.... and you have got any idea of what you might study in the sixth form that would help that?  
B: I dunno. First I need to get my five A-C's for whatever I want to do and then I'm going to get advice from our teachers around the school, and then when I get my final decision – either drama or science I will decide about that but then I think I'll go to university and do my like four year training to be a teacher.  
Int: Okay. Do you know what you have to do to become a teacher?  
B1: Not really but I know you have to get at least five C's to A's.

Whereas the majority of South Bristol Future Brunels say that they want to study at university after their post-16 courses, they do not appear to have an idea about which universities they might apply to. By contrast the North Bristol Future Brunels appear to be more aware of university courses, as for example one girl who would like to become a midwife.

- Int: What do you think you will be doing when you're 25?  
G: I'd like to be a midwife.  
Int: Why's that?  
G: 'Cause I've always been interested in things like biology and medical stuff, and that suits me.  
Int: What are you doing for your A-levels? What do you think you'll be doing?  
G: I'm thinking at the moment biology, maybe English, maybe psychology, sociology and film studies.  
Int: If you train to be a midwife, where would you have to go to do that?  
G: There's loads of universities. Birmingham.

Similarly a Future Brunel from North Bristol who would like to study computer science at University has already started to look at University course.

- Int: Have you looked into the courses?  
B: I have.  
Int: Which ones look interesting to you?  
B: Quite a few universities like York offer courses called Computer Science and Philosophy, which I suppose is analysing the social impact and the theory behind computers instead of just the computers themselves, so it's not just the physical components: it's the ideas behind them.

### **Concluding remarks**

*Do the Future Brunels want to pursue STEM-related careers?* and *Are the Future Brunels able to pursue STEM-related careers?* are key questions for our evaluation of the Future Brunels programme. In section 5 we showed that the majority of Future Brunels are thinking about STEM-related careers, with many of them having shifted towards STEM through participating in the programme. This is particularly remarkable for the Future Brunels who live in the South of the city, given that they are not likely to have access to the types of 'science and engineering capital' that are key to affecting the likelihood of a young person aspiring to STEM-related careers. In this respect we suggest that the Future Brunels programme is achieving its aim of inspiring young people to consider a career in science and engineering.

Whether or not the Future Brunels are able to pursue STEM-related careers relates more to factors beyond the control of the Future Brunels programme than to the programme itself. It relates to whether or not they obtain good-enough GCSE grades to be accepted on the A-level courses they want and maybe need to study. It relates to whether or not they obtain good-enough A-level grades to be accepted on the university courses or apprenticeship programmes they desire to follow. It relates to whether or not they have readily accessible sixth forms where they can study the necessary level 3 courses for access to apprenticeships or higher education. It relates to whether or not they have people around them who know how to navigate the higher education system. In this respect the Future Brunels who live in the South of the city of Bristol are relatively disadvantaged when compared with those who live in the North of the city. We pursue this issue further in the next section of this report.



## Identity, Awareness and Opportunity related to STEM

### Contrasting ways of supporting emerging interests

All of the Future Brunels have aspirations for their future and A-level of confidence about pursuing these aspiration. Furthermore their ambitions and interests are supported by their families. However we have found a contrast in the extent to which these young people and their families know about how to follow up their interests. In particular some of the Future Brunels are not aware of the breadth of opportunities that may be available to them, and the consequences of making certain choices, for example the combinations of subject choices at GCSE level or beyond. This contrast follows the same pattern as we have observed for participation in Higher Education, namely that the opportunities and awareness amongst families in South Bristol is limited by contrast to that amongst families in North Bristol. This is not surprising given the general differences in background and educational experiences of the families in North Bristol from those in South Bristol as discussed in section 6. This suggests that those young people in South Bristol may be disadvantaged with respect to access to the full range of STEM related careers, and in particular those that require specific undergraduate degrees. Within this section we look more closely at some of these differences, highlighting the additional support that could be offered to young people from families who have no experience of Higher Education and little experience of science and engineering within their everyday lives.

### The ground on which the seeds are sown

In South Bristol, the generation to which the parents of these young people belong, was expected to leave school at 16 and to start earning an income (see, e.g. Raphael Reed et al., 2007). In this context, the expectation that their sons and daughters will continue at school until 18 is likely to be unfamiliar to them, giving many families the task of working out what should happen when and who should be providing information about choices. In the following extract, the mother and older sister of one of the Future Brunels describe their frustration with the information that they have received about the subjects and grades necessary to be able to access a course for a chosen career.

- Int        So you wanted to be a vet ... tell me more about that.
- Sister     I wanted to be a vet for ages, and then in my Science I got Cs overall, and I needed a B to carry on with Biology. But I didn't have that so I couldn't go on to do that. So now I have to do Applied Science ... which I can't go on to do Veterinary courses.
- Mum       I can't understand that bit of it.
- Int        What, can't you understand the fact that they can't go on to veterinary without ...
- Mum       It's like [an adult friend] if she wanted to do something, she could go to college to get that degree to become a vet or a teacher or TA or anything like that. And I can't understand why [my daughter], her dream what she wanted to do, just cos she didn't get one grade that she can't carry it on now.
- Mum       But seeing that she is still at school, I'm just surprised that they just say 'well I'm sorry, but you didn't get that grade so you can't do Veterinary'.
- Int        Have you talked to the teachers about that?
- Mum       They'll just ... we went and spoke to that careers man because we always thought she wanted something to do with cookery. And then when she changed and said no she wanted to be a vet, and now they're saying to her well you can be a veterinary nurse.
- Int        But you don't want to do that? Or could you want to be that?
- Sister     I don't know whether Applied Science would get me a course in university.
- Mum       How can you find that out?
- Sister     I've been looking on UCAS and everything but it just says you need Biology and another science. But I've got Applied Science which is all of the sciences. So I'm not really sure.

For those who intend to continue their education after leaving school at 18, access to many university courses in the UK requires particular combinations of subjects, and specified levels of grades at A-level. Entry as a mature student is less clearly prescribed, and universities and colleges will accept a wider variety of qualifications, including specially designed 'access' courses, and also recognise work experience; the mother refers to this through the example of the possibilities open to her adult friend. She contrasts this with the situation for her daughter, who has an ambition to become a vet. The choices available to her daughter appear to have precluded the possibility of following her interest - in particular, because she has been told to study Applied Science at A-level rather than the A-level in Biology that she knows she needs to take if she wants to study Veterinary Sciences at University. The mother's statements indicate a strong belief that her daughter should be able to follow up her interest and dream, just as her adult friend can, and expresses her frustration that an outcome in GCSE biology has led teachers to tell her that she cannot study A-level biology.

We have emphasised this example because it is a counter-example to the widely held view that young people in areas of social deprivation "do not have aspirations". This is an example of a young girl who as her mother says "had a dream to become a vet", a young girl who knows what A-levels she needs to study to become a vet. However, because she obtains a C grade in GCSE biology from a school where historically GCSE results have been relatively low she has not been allowed to study A-level Biology and has been told to study A-level Applied Sciences. Because of the experience that the Future Brunel's older sister has had, the mother is very aware of the importance of GCSE and A-level choices, aware of her own lack of knowledge about pre-requisites for A-level and University courses and aware that she has to rely on the school to provide the necessary opportunities for her daughters. We wonder if the school is able to provide either the advice or the opportunities that are needed – namely that this girl should keep her options open in terms of potential future STEM career choices.

In the interview extract below from an interview from a Future Brunel who attends a school which does not offer post 16 courses, the father describes the process of thinking about what you want to do and making choices towards a chosen career as being closely tied with progress through the school years (quoting year 10, when students are aged 14-15, as the year by which young people should have an idea of what they want to do). The daughter is fully aware that she has the option to go to university, and is confident that she can and will do it, but neither she nor her father describe with any kind of certainty the steps she will need to take, including the step of moving to a school that offers A-level courses.

- Int        And have you thought what you might want to do when you leave school at all?  
 Girl       I want to be a physiotherapist.  
 Int        Oh okay. So tell me more about that  
 Girl       Or like a sports physio, like sports science and stuff like that.  
 Int        Okay, and what would you have to do in order to become a sports science ...  
 Girl       Do sports science, like about the bones and muscles and stuff like that.  
 Int        And where would you do that do you think?  
 Girl       I don't know.  
 Dad       We haven't looked into that have we? I think, it's something I was going to look up after Christmas or towards the end of Year 9, cos I think Year 10, 11 ... Year 10, definitely you need to start having an idea of what you want to do.
- (...)
- Int        So you have to leave your school at 16 I think don't you, is that right?  
 Girl       Yeah I think so.  
 Int        And do you know what ...  
 Girl       But I still have to stay in education until I'm 18.  
 Dad       18 now?  
 Girl       I think I leave at 16 ...



Dad See I don't even know yet see, cos all I know is they've got to stay on at school to 18. I don't know, have you got a 6th Form then?

Girl I don't know.

Int No I don't think they have.

Girl So I think I leave at 16 but I have to stay in education, I have to go to like college.

Dad Or 6th Form somewhere I suppose.

Int Have you thought about that?

Girl Yeah I do want to go to college and university.

Int Okay, so if you went to college after 16, what sort of things would you want to study?

Girl Science and stuff.

Int A-levels would that be?

Girl Yeah.

Int Have you thought about that have you?

Girl A little bit.

Int And then you said you'd like to go to university, what have you thought about then?

Girl Like I could get a science degree, or sports science degree.

Dad We haven't really discussed it ... I don't know if it's too early or not to start discussing things really. It's difficult because, I sometimes wonder whereas to ... cos I remember when I was a kid I changed my mind what I wanted to do so many times.

Int I think the only thing is, when you make your choices, to make sure you don't make choices that mean you can't do something that you might want to do.

Dad When did you have to choose then for this year?

Girl I don't choose like what I want (inaudible) instead of like I have to do like Art and all that, I just choose Art and Cooking.....I'll just do Art and Cooking for the rest of the year.

Dad Then you choose at the end of Year 9 isn't it for what you want to do for the next two years. We'd obviously go through it at the time anyway, she wouldn't make that choice on her own.

In the interview extract below, held with another Future Brunel from the same school, a girl describes her career interests. The resources to which she refers are her own self confidence about working with numbers, and the example of people she knows who are working in fields in which an aptitude for numbers is relevant. She describes her own progress and enjoyment of mathematics as something that will help her get her to what she would like to do, and refers to people that she and her family know who have studied at degree level and are already studying or working in accountancy, business or marketing, the career that she has said she is interested in. At the same time, she and her mother give examples of people who have experienced difficulty in getting the jobs they want, and to the role of perseverance.

Girl Yeah, all my mates want to be hairdressers and teachers

Girl I would do like budgeting and marketing, it's like working out the money and like profits and stuff.

Mum That's accounting. The accounting side of it is working out the profit and loss and the money side of things, whereas your marketing is telling everybody how fantastic it is.

Dad Selling it.

Girl Yeah, so I think that will help me. Because at the moment in Maths I'm working at grade C to B. I'm set to get an A by the end of Year 9, cos I'm doing quite well on my level at the moment.

Girl And we were talking to this lady and she went 'Well I've got degrees in nearly everything, but no one would take me' - didn't she?

Mum She had degrees but she did have a job promise with forensic science with Avon & Somerset, but then the job cut happened or something happened and she was just pushed aside. Yeah ... but if you don't persevere then you're not going to get it are you?

Int So who do you know well who's been to college and university? Have you got ...

Mum Yeah, my sister's kids.

Int have they ... and what have they gone on to do?

Mum (x)'s doing accountancy. And (y) is in marketing at the moment, but she's trying to get back in ... she did Business and Marketing with Lloyds briefly, and then the position that she was promised never happened, and one thing and another, as it does ... but she is going for another job at the moment.

What is striking in this example is the girl's confidence in her own ability, and her source of examples and inspiration (particularly about the need to persevere) from within the family. However, the discussion also suggests that she is unaware of the breadth of careers open to someone with an interest and aptitude in mathematics.

The following extract is taken from an interview with another family, and chosen because it gives a very clear example of something that we have found amongst families of Future Brunels who attend either of the two schools in North Bristol. In the extract, the parents show a recognition of their son's interest and abilities that is similar to those of the girl in the example above, in which the girl's ability with mathematics is seen as setting her on a trajectory, one that will see her following the example of other, older family members who have been to college or university. By contrast, in the discussion about their son's abilities and interests below, the parents explicitly link what he does as a hobby to a vision of him becoming someone who will do something useful, give examples of how scientific knowledge (for example, the concept of power) may come to be helpful to his personal projects, and discuss how thinking about what questions to ask will develop and enrich his interests. In this family, school science is talked about as something that will help you think about things that you already enjoy doing, and the question of what you will become or how you will become it, is something that will emerge out of a combination of interests and study rather than being planned at points that are structured by the school system:

Dad I'm hoping that with the programming and a little bit of practical knowledge he could be quite useful. (...) If things are kind of designed numerically by engineers who understand what should happen, and then he can somehow put the two things together.

Mum And ..., it's really nice actually beginning to value the programming, because I think we have ... [boy] has loved doing computer games ... you've loved doing it, and you've had to plough through quite a lot of 'Oh I can't believe you're on the computer again' haven't you? And although we've maybe got a few more rules around the edges now, it doesn't feel so bad when it's actually creating something. And then we can sort of talk about ...

Dad I'd like it if we'd have sat down and worked out how fast you can push that car with numbers, to know how much power we've got and how much propeller we've got and ... yeah and knew how fast ... then we'd know if we were flogging a dead horse trying to get it to go any faster. (laughs)

Mum Yeah I still think with programming the key thing is making the right question and ... you can probably spend a long time programming something that's not very useful, but you need to think of what the question you're trying to answer with the program is.

Dad Yeah anyway we'll work on it – work in progress.

Int: So of the things that you do at school, things you study at school, what do you think's useful for ... which of them do you think play a role in your future? ...the sort of subjects that you learn at school.

Boy I think all of them really ... well most of the ones ... most of the obvious ones like English, Maths, Tech, IT, Science ...

Dad I think they do make your brain work don't they?

What is very clear, in each of these examples, is the young people's awareness that they have ability and potential, a rich ground into which the Future Brunels programme can sow the seeds that it hopes will ultimately grow into a lifelong interest in science, technology, engineering and mathematics. For this to happen, these seeds will need to be nourished from other sources, most importantly by school subject lessons, but also by others who, through their words or actions, can show the young person how what they are interested in links with activities or behaviours that are less exciting; persevering, sticking with school subjects even when they seem boring, developing a habit about thinking what question you are trying to answer, and so on.

In the case of the boy from North Bristol, it is clear that the sources that will nurture his interests exist within the home, in the form of his parents, and that he and his parents are already aware of the variety of school subjects that are relevant to his potential career. By contrast in the first three examples the young people have expectations that there are steps towards achieving their vision, and the nature of those steps and the means to take them is a body of knowledge that they are unfamiliar with, knowledge which is not picked up from peers, family members or incidental discussion with other parents but from the school system - as in the family who explain their discovery that a C grade in Biology has closed the door to studying towards being a vet, a father who says *all I know is they've got to stay on at school to 18*, the girl who refers to her own progress in mathematics as something that will help her get her to her chosen occupation (but does not indicate any awareness of other aspects of the educational journey). These effectively correspond to two very different stories about how a Future Brunel in whom the seeds of interest in STEM have been planted, might eventually become a scientist, engineer or mathematician:

- a) For families with experience and awareness of Higher Education, the way to support a young person to take up STEM subjects and careers is equated with following up and developing their emerging interests in science, and keeping options open. When specific subjects are chosen at school, the young person is advised to make choices that allow the possibility of taking up science or engineering at higher levels of study.
- b) For those for whom Higher Education is unfamiliar, the way to support a young person becoming a scientist or engineer begins at the point when they identify that they see themselves as someone in a science related job or career, and is concerned with negotiating the structures and systems for advice available within the school system in order to work towards that goal.

There are several very clear differences between these approaches that have implications for the Future Brunels programme. The first difference concerns the development of imagined identities as scientists. In category (b), support is given in relation to an imagined identity in a particular role or in a certain kind of career. By contrast, in category (a) the possibilities are left open for the young person to explore possible identities and for their imagined selves to develop and change. In either case, activities that provide the young person with a sense of who they might become, will be of value. However, for those in category (b) the point in time at which the young person is able to describe themselves as a particular kind of scientist is crucial, since early identification of oneself as someone who will follow a particular career path will increase the chance that appropriate steps will be taken.

The second difference is closely associated with the first and concerns the availability and nature of role models, or, to be more specific, people with whom the young person can identify and say 'I want to be like that'. For those who come from communities in which Higher Education is relatively new, there is a smaller pool of people to draw on as role models.

The third difference is that in category (a), the ground is already fertile, in the sense that aspects of family life such as discussions, leisure activities and out of school activities are readily organised for encouraging academic interests and helping them develop, then planting the seed of interest in science, may be sufficient. To use another metaphor, lighting the match of interest in science is sufficient, since the flames will be fanned by those at school and home. In category (b), lighting the match, or planting the seed, may well start a process, but it is more likely to be the actions and determination of the young person themselves in steering that interest and in harnessing the support of others, that enables it to burst into growth.

### **Equal opportunities**

Not surprisingly those Future Brunel from families where there is neither experience of Higher Education nor experience of working with STEM subjects have a more restricted set of resources to draw upon when thinking about their future career possibilities and related educational pathways than those from families with experience in these areas. As discussed within section 6 these are generally the Future Brunels from schools in South Bristol. In many respects we are only drawing attention to the social class divides in our society that are widely reported elsewhere (e.g. Carnegie Corporation of New York and The Sutton Trust (2008, 2012); Kirby, (2016)).

We recognise that it is difficult to discuss social class related differences without inadvertently slipping into a deficit model of thinking. Furthermore, in a desire to treat all young people as equal the structural differences in society that relate to differential opportunities are often overlooked. We noticed that when we presented the results of our evaluation to an advisory group which included members of the senior leadership teams of the participating schools, there was a reluctance to openly discuss the differences between the educational backgrounds of the South Bristol and North Bristol families and also a reluctance to discuss the differences in educational opportunities.

It is important that all Future Brunels are able to have contact with people with whom they can identify and say 'I want to be like that' since early identification of oneself as someone who will follow a particular career path will increase the chance that appropriate steps can be taken. To a certain extent this is what the Future Brunels Programme offers. However we suggest that there is considerable potential to be explored in providing opportunities for young people from South Bristol to develop informal contact with people who can become role models and be closely involved with school subject choices. This could be provided by their schools or by other organisations in the local area, for example the South Bristol Youth Programme.<sup>10</sup>

We also believe that for those young people in South Bristol early identification of themselves as a potential scientist or engineer is crucial in order to increase the chances that appropriate GCSE choices are made. Some of the Future Brunels, for example, were not able to take triple science at GCSE level and this may limit their A-level and subsequent degree and career choices. Furthermore many sixth forms and sixth form colleges will not accept students onto A-level science courses without at least a Grade B in GCSE double or triple science. The implication is that a significant way in which a programme such as the Future Brunels project can assist young people is by encouraging students to choose GCE subjects that will keep options open further down the line, and supporting them in realising that decision.

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<sup>10</sup> <http://southbristoloyouth.com/our-projects/>

## Conclusions and Recommendations

### Inspiring young people to explore STEM-related careers

At the beginning of the programme just over half of the Future Brunels from across the first three cohorts had not chosen STEM-related careers or were unsure about their future careers. By the end of the programme all of the first three cohorts of the Future Brunels are either thinking about STEM-related careers or are keeping their options open by choosing to study a selection of science A-levels. In this respect we consider that the Future Brunels programme is achieving its aim of inspiring young people to explore careers in science, technology, engineering and mathematics.

However the opportunities to pursue STEM related careers are more restricted for the Future Brunels who live in the South of the City by comparison with those who live in the North of the City. This relates to factors beyond the control of the Future Brunels programme which include: GCSE grades; accessible sixth forms for studying level 3 courses; access to people who know about STEM-related careers and access to people who know how to navigate the higher education system.

### Characteristics of the Future Brunels Programme

The Future Brunels programme occupies a particular position within an ecology of science and engineering-related activities, and works with young people and their families as well as schools. There are a range of opportunities that open up for the Future Brunels through their involvement in the programme, and these relate to identity formation, learning experiences, conversations and networks. Overall we consider the following to be key characteristics of the Future Brunels programme:

- A development team who: are creative; are willing to take risks and pursue excellence.
- A focus on the engineering practices of Isambard Kingdom Brunel.
- An emphasis on Future Brunels becoming part of the ss Great Britain community.
- An emphasis on integrating the practices of both engineering and science throughout the programme.
- Giving Future Brunels access to the working life of engineers and scientists.
- Enabling Future Brunels to engage with scientists and engineers.
- Allowing Future Brunels to have-a-go themselves.
- Supporting STEM work experience.

**Recommendation 1:** Research suggests that a key factor affecting the likelihood of a student aspiring to a science-related career by the age of 14 is the presence, within the family, of science-related qualifications, understanding, knowledge (about science and ‘how it works’), interest and social contacts (e.g. knowing someone who works in a science-related job). This is referred to as *science capital*:

(<http://www.kcl.ac.uk/sspp/departments/education/research/aspires>). The Future Brunels programme should find ways of further exploiting their network of scientists and engineers to develop the *science capital* of the participants, and in particular the Future Brunels who do not have access to such capital through their family and friends. There is considerable potential to be explored in providing opportunities for young people who do not have access to science capital to develop informal contact with people who can become role models and



be closely involved with school subject choices. This could be provided by their schools or by other organisations in the local area, for example the South Bristol Youth Programme<sup>11</sup>.

**Recommendation 2:** Within any expansion of the Future Brunels programme it is important to consider the balance between students that do not have access to science capital and those that do have access to such capital. On the one hand from a social justice perspective it is important to provide opportunities for young people who do not have access to science capital. On the other hand having a mix of students with and without access to science capital is in itself potentially valuable in terms of expanding access to science capital for those young people with little access.

**Recommendation 3:** The Future Brunels programme should work with schools and key policy makers in the city so that they become more aware of the relative disadvantages in terms of being able to pursue STEM-related careers for many young people in a City such as Bristol.

**Recommendation 4:** The Future Brunels programme should work with schools, parents and other local organisations to find ways for Future Brunels from families who have little experience of A-level/higher degrees to learn how to navigate the system and obtain advice about GCSE choices and A-level choices in order to keep their options open for potential STEM-related careers. The earlier that a young person becomes aware of the constraints within the system that may prevent them from achieving their aspirations the more likely it is that they can harness the necessary support.

**Recommendation 5:** The Future Brunels programme should consider incorporating exposure to a wider range of STEM-related careers, for example computer programming and architecture.

**Recommendation 6:** In order to inform the development of the Future Brunels programme, the programme team should develop an understanding of the relationship between young people's interest in STEM subjects and careers and the elements of the programme that are significant to them, i.e. engagement in practical activities, personal informal contact with young scientists and engineers, and opportunities to see what the daily working practices of an engineer or scientist might involve.

**Recommendation 7:** The activities and results of the Future Brunels programme should be disseminated to policymakers, practitioners, and those working in the fields of science education and the museums and heritage industry.

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<sup>11</sup> <http://www.southbristoloyouth.org.uk>

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## Appendices

### Appendix 1: Methodological Appendix

#### Participants

This report compiles information collected from the first three cohorts of Future Brunels, who joined the programme in 2011, 2012 and 2013 respectively. Each cohort consisted of six girls and six boys, who were aged 11-12 at the time they first became Future Brunels, and would be 15-16 when they graduated from the programme. The evaluation makes use of material collected from these 36 young people, 18 of whom were girls, and 18 were boys, and of whom 9 were students at Merchants Academy, 9 at Bedminster Down School, 9 at Redland Green School and 9 at Cotham School. The first two schools are situated in South Bristol and the others in North Bristol; although it had not been the intention of the programme organisers to choose schools from areas with distinct socio-economic profiles, demographic data about the areas show that there are significant differences between the two areas, as is discussed in the body of the report.

#### Research Tools

The Evaluation Team used observation, interviews, focus groups, and questionnaires to collect information about the programme and the opinions, experiences and development of the young people who participated in it, as described briefly below:

##### Observation

This enabled the research team to spend time with the Future Brunels and the ss Great Britain team and to familiarise themselves with the organisation of the activity days. The purpose was to observe the delivery of the Future Brunels programme and to capture first hand participants' views, behaviour and interactions.

##### Interviews with Future Brunels and their families.

##### Semi structured interviews

Interviews took place with young people and their families soon after they joined the project, and again after two years. Semi Structured interviews allow freedom for families to expand on points that they felt were more relevant.

The schedule of questions that we prepared for the initial interview was designed to gather information from families about the Future Brunel's engagement in out-of-school communities of practice, about their school communities, and about imagined future identities. We asked about the interests of the Future Brunel and other members of the family and how they spent their leisure time; about the Future Brunels own ideas about the future and the education histories of their parents; about activities at the ss Great Britain and other trips with the Future Brunels and for their own stories of the selection process for Future Brunels.

The interviews that took place two years later allowed the research team to explore issues arising from participant observations. We asked the Future Brunels to talk about the trips and activities they had participated in, to tell us the subjects that they had chosen to study at GCSE level, to talk about their interest and enjoyment in science and tell us what connections they made between school science and the activities they'd participated in at the Future Brunels.

##### Questionnaires

At the end of the summer term 2015, Cohort 1, Cohort 2 and Cohort 3 filled in a questionnaire, which asked them to give information as follows:



- To mark a list of activities with their three most- and least- preferred and to give the reason why.
- To mark the extent to which they agreed or disagreed with a series of sixteen statements about the impact of the project.
- To list the GCSEs which they had taken, or (for cohorts 2 and 3) for which they had enrolled.
- To list the A-level subjects that they had chosen or which they anticipated they might choose.
- To indicate whether they planned to go on to apprenticeship or Higher Education and which subjects they would study.
- To say what they thought they might be doing at age 25.

### **Focus Groups**

Focus group interviews were carried out in each of the four schools between November 2015 and January 2016. The aims were to probe the influences on Future Brunels when thinking about choices at school, possible jobs/career, imagined future identities, and views about the programme. The three main areas for questions were:

- Ideas and plans for the future.
- What difference the Future Brunels programme made to you?
- What is a 'good' activity day?

Focus groups were held with members of the second and third cohorts. Members of the first cohort were not involved in focus group meetings as they had graduated from the Future Brunels programme and moved on to sixth form and/or apprenticeships.

### **School Data**

Official statistics collected on schools, children and young people and made available to the public by the Department for Education. For more information see <https://www.gov.uk/government/organisations/department-for-education/about/statistics> and <https://www.gov.uk/government/organisations/ofsted>

### **Staff Interviews**

Interviews were held with the Education Team at the ss Great Britain and with members of school staff at the four schools. These were used as a way of gaining a deeper insight into both the expectations of the project and the perceptions of changes observed by members of staff.

### **Future Brunels' Logs**

The Education Team concluded each activity day with a request to the Future Brunels to write a log of the day's experience and email it back to the team. The Evaluation Team read a selection of the logs returned by the young people, which gave further insights into young people's experience of the project and helped with the planning of semi structured interviews with the Future Brunels and their families during their second year of involvement in the programme.

### **Data Collected**

In total, the research team:

- Spent around 142 hours conducting observations.
- Conducted 42 family interviews.
- Facilitated 4 focus groups (with Future Brunels in Cohort 1).
- Conducted 2 staff interviews with the Education Team at the ss Great Britain.
- Conducted interviews with staff from 3 of the 4 schools involved.
- Collected 36 completed questionnaires.

## Appendix 2: Future Brunels Example Programme

Year 7 The Scientist	Year 8 The Polymath	Year 9 The Magician	Year 10 The Engineer	Year 11 The Human being
	Art and Science activities, viewing stereoscopic images and Brunel collection.	Magic/science show. Exploring the science behind illusions	Exploring Bristol's engineering heritage. Visit to Clifton Suspension bridge, going inside the abutments.	Visit to Southmead Hospital. The impact of science and technology on our health.
	Family welcome evening			
	Pinhole camera activity day on board ship. Exploring the physics of light and making a pinhole camera.	Hack activity. Investigating behind the scenes of technology.	Visit to Dymag and National Composite Centre. Exploring the future of composite materials.	Forensic Science activity at UWE CSI house. Genetic data, use and potential mis-use.
First round of selection process, held in schools and supported by BICA members	Black and white photography. Chemical processing in darkroom	Babcock visit. Understanding technological developments and exploring future technology	Visit to Renishaw. Metrology, medical and engineering innovation.	Visit to Hinkley Point B. Exploring nuclear power and energy provision.
Second round of selection process, held on site. Bridge building challenge.	Music technology. Visit to dBs and music production.	Visit to University of Bristol. Sonic levitation and quantum photonics	Visit to Bristol UWE fabrication lab. Creating a Rube Goldberg machine	Robotics workshop. The future of robotics and the impact on human lives and our world.
Introductory day at Brunel's ss Great Britain. Chemistry challenge and introduction to Brunel Institute	Animation workshop, exploring the use of technology to create simple animations	Visit to sewage treatment works. What's behind an everyday process?	Rolls-Royce visit and tour. Exploring aeronautical engineering.	
Trip to Thorpe Park. Rollercoaster science and engineering.	Aardman visit. Exploring science and engineering in a creative industry	Coding activity day. How do we programme computers?	Visit to London. Exploring The Shard with an engineer, how do you design and build the EU's tallest building?	Graduation

## Appendix 3: Reports Produced

### 'Snapshot' reports

- **June 2012.** Evaluation of the Future Brunels' Programme Cohort 1: Preliminary Report.
- **January 2013.** Evaluation of the Future Brunels' Programme Cohort 2: Preliminary Report.
- **July 2014.** Evaluation of the Future Brunels' Programme Cohort 3: Preliminary Report.

### Full reports

- **September 2012.** Evaluation of the Future Brunels Programme Year 1: 2011-2012.
- **October 2013.** Evaluation of the Future Brunels Programme Report for Year 2. The first cohort: 2011-2013.

### Internal reports

- **October 2015.** Cohort 1 of the Future Brunels at the end of the programme.
- **November 2015.** Cohort 2 of the Future Brunels after three years in the programme.
- **December 2015.** Cohort 3 of the Future Brunels after two years in the programme.

